SEISMIC PERFORMANCE OF SHELL STRUCTURE UNDER EARTHQUAKE LOADING

RAHAMAH WATI BINTI SULAEMAN

B.ENG (HONS.) OF CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name	: **RAHAMAH WATI BINTI SULAEMAN**
Date of birth	: **20TH APRIL 1994**
Title	: **SEISMIC PERFORMANCE OF SHELL STRUCTURE UNDER EARTHQUAKE LOADING**
Academic Session	: **2016/2017**

I declare that this thesis is classified as:

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*

☐ **RESTRICTED** (Contains restricted information as specified by the organization where research was done)*

☑ **OPEN ACCESS** I agree that my thesis to be published as online open access (full text)

I acknowledged that University Malaysia Pahang reserves the right as follows:

1. The thesis is the property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

STUDENT'S SIGNATURE	**SIGNATURE OF SUPERVISOR**
(940420-12-5054)	**(IR SAFFUAN BIN WAN AHMAD)**
Date: JANUARY 2017	Date: JANUARY 2017

SEISMIC PERFORMANCE OF SHELL STRUCTURE UNDER EARTHQUAKE LOADING

RAHAMAH WATI BINTI SULAEMAN

Thesis submitted in fulfilment of the requirement for the degree of Bachelor (Hons.) of Civil Engineering

Faculty of Civil Engineering and Earth Resource
UNIVERSITI MALAYSIA PAHANG

JANUARY 20117

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor (Hons.) of Civil Engineering.

Signature :

Name of Supervisor : IR SAFFUAN BIN WAN AHMAD

Position : LECTURER

Date : JANUARY 2017

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award for other degree.

Signature :

Name : RAHAMAH WATI BINTI SULAEMAN

ID NUMBER : AA13087

Date : JANUARY 2017

DEDICATED

To

My Mother
A strong and gentle soul who taught me to trust in Allah , believe in hard work and supporting my financial .

My Siblings
For supporting and encouraging me to finished my thesis.

My Best friends
For make me laugh more than i use to.
“Soulmates”

ACKNOWLEDGEMENT

I thank the Almighty God for giving me strength and allowing me to complete this work. I wish to express my sincere gratitude to my supervisor , IR .Saffuan Bin Wan Ahmad who have been a brilliant supervisor to me. I would like to thank you for your never ending support during my tenure as research student under your guidance , for giving insightful comments and suggestion of which without it , my research path would be difficult one. Your advice on my research has been valuable

Special Thanks to my family especially to my mom Rusmiati Binti Madi always supporting me especially in financial and the prayers to me complete this thesis in peace .Words cannot express how grateful I am to my family.

I would also like to thank you to all lectures faculty Civil Engineering which always motivate me to complete my degree.

And Finally, i would like to thank to all my close friends who supported me and motivate me to strive towards my goal .

ABSTRACT

During past recent years, the number of building structural damage affected by earthquake is increase in Malaysia especially in Sabah. The reason of failure the structure because of inadequate design by Engineer without considering seismic effect in while designing the structure. Designing the structure must be considered several parameters such as the frequency of building can resists, the displacement and acceleration of the building . The mode shape should be study furthermore, which is the tendency of building will move during earthquake attack from the studies the engineer should be able to predict how to overcome when the problem occur.SAP2000 use to conducted the analysis , SAP2000 able to determine the best mode shape which is the best frequency and period of structure to built. The maximum acceleration and displacement are able to find out by using SAP2000. The best mode shape in this analysis are from mode shape 1 which is the frequency is 68.02 Hz and the period is 0.014701 sec . Maximum acceleration is 149442.9433 m/sec2 from axis Y and the value are get from the joint 128 . The highest displacement also occur from joint 128 at the Y axis where is the value are 0.299743 m. To design new spherical dome , we used 5% of damping which is the value maximum acceleration and displacement at the joint 128 used in the design later .

ABSTRAK

Semenjak tahun kebelakangn ini,bilangan stuktur bangunan yang rosak disebabkan oleh gempa bumi meningkat di Malaysia terutamanya di Sabah . Faktor utama kerosakan tersebut berlaku di sebabkan jurutera tidak mengambil berat faktor seismik ketika mereka bentuk bangunan. Mereka bentuk bangunan haruslah menitik beratkan beberapa faktor seperti frikuensi bangunan yang dapat bertahan ketika gempa bumi berlaku , anjakan dan pecutan bangunan stuktur tersebut. Bentuk mod perlu dikaji secara terperinci kerana ia akan menunujukkan kecenderunagn sesuatu bangunan tersebut bergerak semasa gempa bumi berlaku dan secara tidak langsung ia dapat mengatasi masalah tersebut.SAP2000 digunakan untuk menjalakan analisis , SAP2000 dapat menentukan Mod yang terbaik dan frekuensi terbaik untuk stuktur yang akan dibina. Data pecutan maksimum dan ajakan dapat diketahui dengan menggunakan SAP2000. Mod terbaik dalam analisis ini ialah dari bentuk mod 1 dengn nilai frekuensi 68.02Hz dan tempoh adalah 0.014701 sec. Pecutan maksimum adalah 149442.9433 m / sec2 dari paksi Y dan nialai ini terbentuk di titik 128. Anjakan tertinggi juga berlaku pada titik 128 di paksi Y. Anjakan tertinggi juga berlaku pada titik 128 di paksi Y di mana nilai ia adalah 0.299743 m. Untuk mereka bentuk kubah bulat baru, kami menggunakan 5% daripada redaman yang pecutan nilai maksimum dan anjakan di bersama 128 digunakan dalam reka bentuk kemudi.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOL

%	Percentage
Km/sec	Kilometre per second
MPA	Mega Pascal
/sec	Per second
kN	Kilo Newton
kNm	Kilo Newton meter
mm	Millimeter
mm^2	Millimeter square
T	torsion
V	shear
b	Section width
d	Effective depth
A	Area
VEd	Shear force
kNm/m	Kilo Newton meter per meter.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Earthquakes are the most devastating natural hazard to life on this planet. Through history they have destroyed cities on every continent. A feature of earthquake is that although the interval between events may be large, the total destruction that occurs and the suddenness of these events is such that they remain one of mankind's most feared natural phenomena . Damage incurred is instantaneous and in many cases total .

Jabatan Mineral and Geosains Malaysia (JMGM) conduct a study related to the seismotectonic setting. Based on their study, Malaysia are country with low seismicity except for Sabah state. Nevertheless, the study also showed that Malaysia are surrounded by Indonesia and Philippines which is the most semically active countries in the region with frequent earthquake events. From this situation the tendency of Malaysia at certain degree for having earthquake risk are higher, particularly in Sabah.

Most buildings in Malaysia does not implement earthquake specification when designing a structure. On 5 June 2015 Malaysian was shock by earthquake 6.0 on the Richter scale "It was the strongest earthquake ever recorded in Malaysia, striking Ranau at 7.15am on that fateful Friday and surpassing the 5.8 tremblor recorded"(malaymail ,2016) . There are several serious damage cause by the earthquake such as damage on the hostels and rest house near the summit of Mount Kinabalu. Some of resident houses near with Mount Kinabalu are effected, several houses are undergoes serious crack and damaging . The reported says there are 23 schools in six different districts are effected and mosque was also damaged due to the tremor .

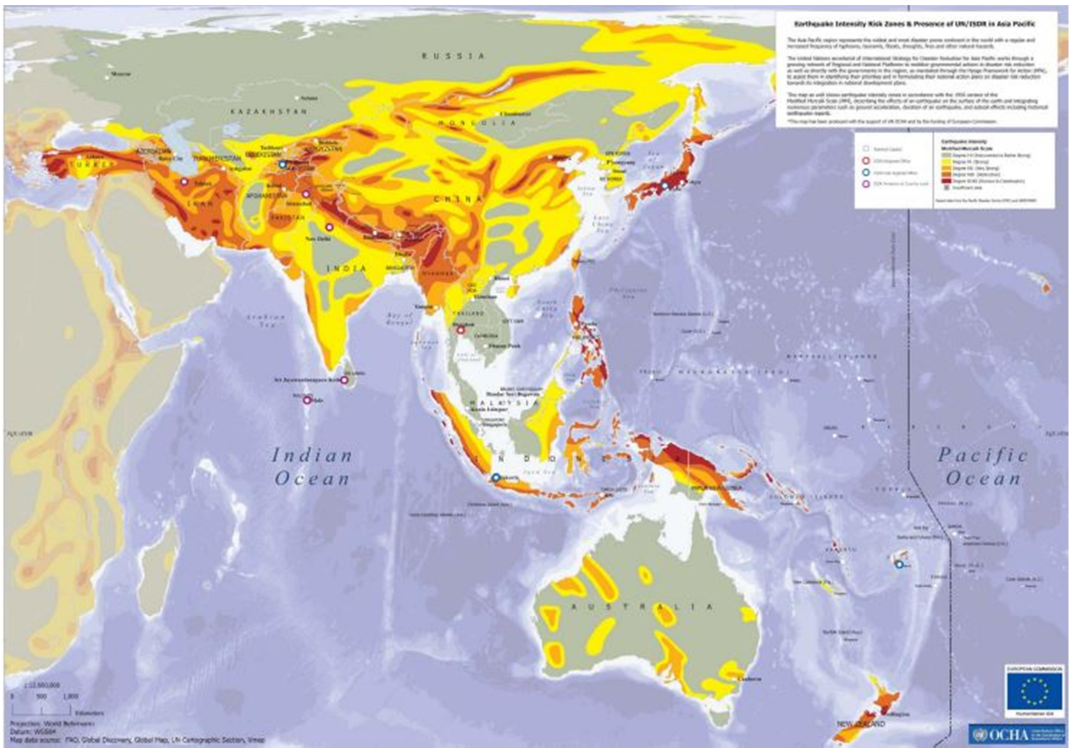


Figure 1.1: Earthquake intensity risk zones and presence of UNISDR.

Source: http://www.preventionweb.net/english/professional/maps/v.php?id=3285

Figure 1.1 shows he intensity zones in accordance with version modified Mercallo Scale (MMS) . The zones indicate where there is a probability of 20 percent that degrees of intensity shown on the map will be exceeded in 50 years (prevention web) .

The main religion in Malaysia is Islam which is most of the citizen are practices Islam in their live . The number of people using mosque are higher since since most of citizen of Malaysia practising Islam in their life , especially on Friday the number of people will much higher compare to the other day . This study will include the effect of shell structure which is widely used in Malaysia not only mosque , stadium , government buildings are also design using shell structure . Study should be conducted to see the effect of seismic load on shell structure especially in Sabah , Malaysia .To make the building are safe to used , the several study should be conducted on that building before designing , since the building are already built the study only focus the behaviour of the building when earthquake are hit the area .

1.2 PROBLEM STATEMENT

Malaysia is near to seismic zone and the neighbour with country such as Philippine and Indonesia which is always having an earthquake and the wave can be feel in Malaysia. From the tragedy June 2015 in Ranau Sabah show us the important including seismic design in our structure . Even the probability of earthquake happened in Malaysia are lower , but we must to ensure our building are safe to live during existing earthquake .Beside that , the citizen should learn how to act and handle when the earthquake hit the area , the study should be necessary to conducted because of most of our citizen are doesn't know how toact during earthquake happened.

Shell structure widely use in Malaysia such as mosque, shopping mall , government buildings and etc , the buildings are the main focus of people . Example of existing building using dome structure is Putrajaya , Unimap Library and so on . We can see most of the building using dome structure are building will always be main focus by the citizen . The safety of people inside the building should be consider by designing the structure include all expect such as wind load and earthquake load . Earthquake load should be include inside the design of the building to make sure the buildings are safe to use .

1.3 RESEARCH OBJECTIVE

There are many matters that require to be analysed in this studied , but the main objectives of this research are:

i. To Study the behaviour of shell under far field earthquake loading .
ii. To determine the displacement and acceleration of shell .
iii. To study dynamic characteristic of shell.

1.4 SCOPE OF STUDY

The scope of study are :

i. Uses of shell structure widely use in Malaysia especially spherical dome.
ii. Time history of seismic analysis will be referring ache seismic effect.
iii. The analysis will involve several things :
    - The behaviour shell when the earthquake loading imposed on the shell structure
    - Dynamic characteristic shell
    - The displacement and acceleration of the shell structure by imposed the
    - Earthquake loading

iv. Using SAP 2000 as a software to analysed the structure

1.5 SIGNIFICANT OF STUDY

The proposed of research is to analysed shell structure which is used at the mosque .At the end of research , student should be able to identify the behaviour of shell under far field earthquake loading . Next , able to know the displacement and acceleration of structure .Identify dynamic characteristic of shell under earthquake loading .

CHAPTER 2

LITEREATURE REVIEW

2.1 INTRODUCTION

Every day parts of the surface of the earth are related by earthquake tremors and some region are shaken violently. During earthquake the buildings will undergo dynamic motion, structure will be the most dangerous places to stand **.** The percentage of people die because of damage of structure are the most highest compare to the other factor after tsunami . On march 2011 , world just shocked by the largest earthquake in japan with 9.0 magnitude . The effects from the earthquake can be felt from Norway to Antarctica. The largest effect can be felt from this earthquake are Tsunami suddenly hit the town after an hour , from this matter the number of death recorded is 15, 891 people and 2,500 people are still reported missing. Nuclear Power Plant on that area also effected and release radioactive material and because of this many of country's nuclear closed due to the safety .

The country having deadliest largest earthquake and tsunami goes to Banda Aceh, Sumatra Indonesia with magnitude 9.1 that kill almost 230 , 000 people . "*Record-setting features of the Sumatra-Andaman earthquake of Dec. 26, 2004, include the longest fault rupture ever observed (720 to 780 miles or 1,200 to 1,300 kilometers) and the longest duration of faulting (at least 10 minutes). The aftershocks included the most energetic earthquake swarmever observed"*(National science foundation ,May 2005) . Earthquake rapped many living things and can destroy a city in a minute .

Figure 2.1: view of damage Sukuiso, Japan a week after the earthquake , Dylan McCord. U.S. Navy (live science , 2015)

Figure 2.2: Devastation of the coastal city of Banda Aceh, Indonesia, after the 2004 Indian Ocean tsunami

2.1.1 Factor of earthquake

Earthquake are broad bonded vibratory ground motion , resulting from a number of causes which is tectonic ground motion , volcanism landslide , rock burst and manmade explosion . The most reason is tectonic ground motion, which is cause by the sudden movement of faults within the crust. There are total 15 large plate on earth , showed in figure 1 , **“ tectonic earthquake result from motion between a number large plates comprising the earth crust or lithosphere”**. Movement of plate are produced from strain energy accumulates in the plates which is driven generated heat from the earth’s core and cause the two side of fault slip between each other .

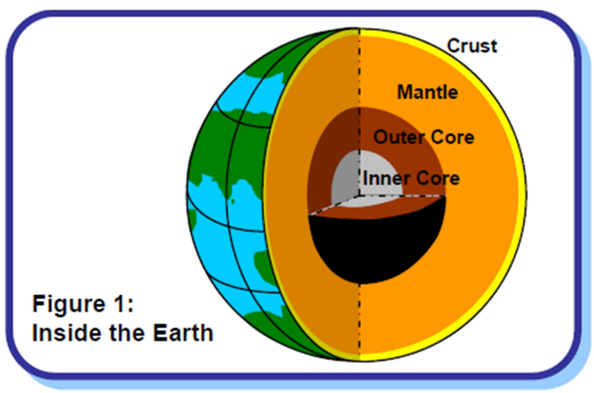


Figure 2.3: Inside the earth

Adopted from: C.V.R Murthy ,2013

2.1.1.1 Plate Tectonics

Plate tectonic (from Greek tecton , meaning on who construct and destroy) . The surface of earth consists of seven major tectonics plate that moves in different directions and any different speeds from those of the neighbouring ones .Tectonic plate is made of elastic strain energy stored during deformation due to the gigantic tectonic plate actions taking place actions taking place in the earth . When Earth crust’s reached its strength suddenly movement will take place at the interface of the plates (called the fault) . The *fault* suddenly slips and release the large elastic strain energy stored in the rocks at the interface. The suddenly slip at the fault causes the earthquake , a violent shaking of the earth during which large elastic strain energy released spreads out in the form of seismic waves that travel through the body and along the surface of the earth . after the earthquake is over , the process of strain build-up at this modified interface between the tectonic plates start all over again , figure shows the elastic rebound theory .

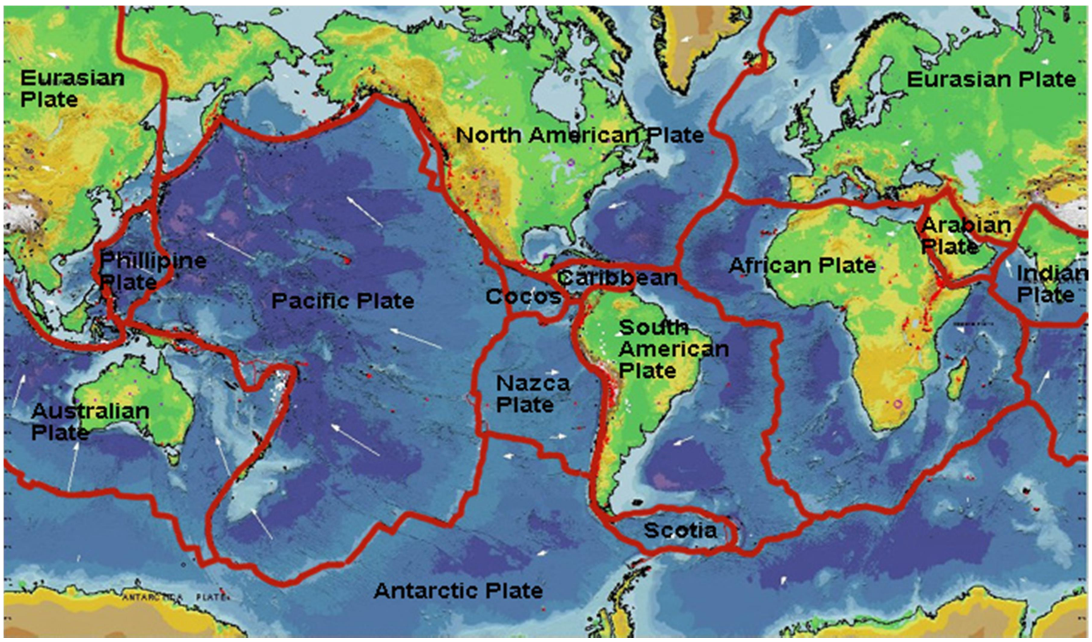


Figure 2.4: The elastic rebound theory

Source : https://www.usgs.gov/

2.1.2 Type of earthquake and faults

Most earthquake in the world occur along the boundaries of tectonic are calls *inter-plate earth-quake* (e.g., 1897 Assam (India) earthquake) . A number of earthquakes also occur within the plate itself but away from the plate boundaries(e.g., 1993 Latur (India) earthquake); these are called *Intra-plate Earthquake* . All the stress and strain produced by moving plates builds up in the Earth's rocky crust until it simply can't take it any more. When all of them crack , the rocks breaks and the two rocky blocks move in opposite direction along a more or less planar fracture surface called a fault . The sudden movement generates an earthquake at a point we called focus . The energy from the earthquake spreads out as seismic waves in all directions.The epicenter of the earthquake is the location where seismic waves reach the surface directly above the focus.

2.1.2.1 Normal fault

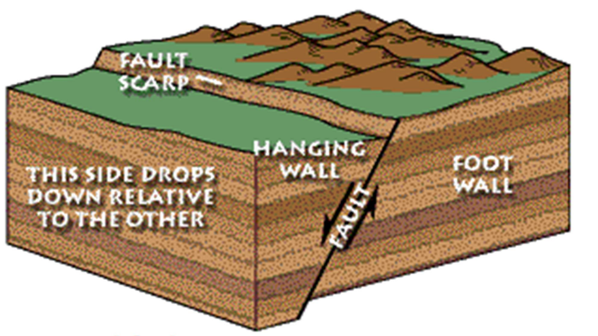


Figure 2.5: Normal fault motion

Normal fault forms when the crust is stretched, tensioned and pull apart. The rock on fault down drops to the other side .

2.1.2. 2Reverse fault

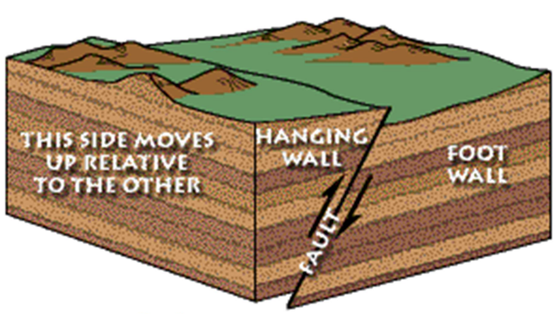


Figure 2.6 : reverse fault motion

Two rocky blocks on either side of a fault move relative each other. Along that a rock above are push upward . Reverse fault caused by compressional forces and shortening will happen and fracture of crust occurs are weak.

2.1.2.3 Strike - Slip fault

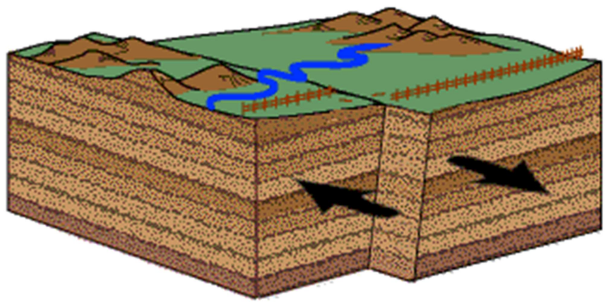


Figure 2.7: slip fault motion

Consists of different type of movement called Strike- slip fault. The movement of fault is horizontal and caused by shearing force.

2.1.3 Seismic waves

During an earthquake occur, it will released large strain energy and the seismic waves will travel in all directions through the Earth's layers. These seismic waves will refracting and reflecting at each interface. (Ucl.ac.uk, 2015)

2.1.3.1 Body Waves

Body wave, one of the type of the wave in seismic wave. There are two type of body wave , P-waves and S-waves. Rock are moved just like the sound wave push and pulled pushed and pull the air by compression and dilatation.

2.1.3.1.1 P-Waves

It is also called Pressure waves or Primary waves. It is longitudinal waves, it is involve in compression and refraction . P-waves is the fastest waves traveling which is the velocity is 5 to 7 km /sec in solids and it is also the first wave appear on a seismogram. It can traveling in many form such rock, fluids and solids.

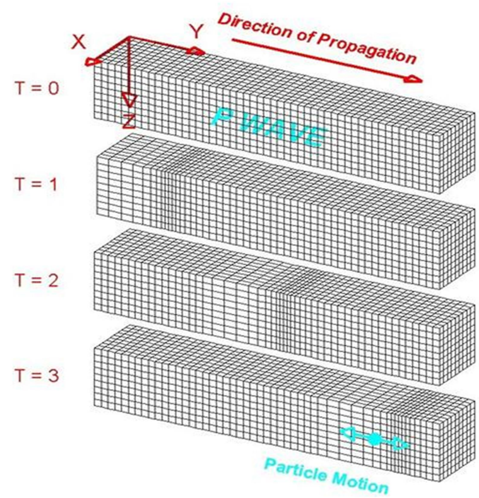


Figure 2.8: P-waves action

Source : (UPseis,2016)

2.1.3.1.2 S-Waves

It is also called Shear waves or Secondary waves , which second wave we can feel in earthquake . The type of wave is transverse waves because it moved in perpendicularly to the direction of propagation. S-waves more slower than P -waves and only can traveling in solid form only which the velocity is 3 to 4 km /sec

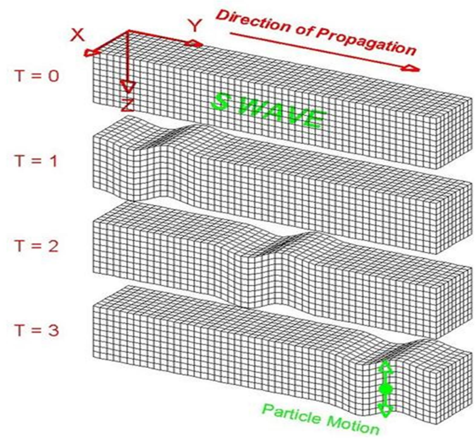


Figure 2.9: S-waves action

Source : (UPseis,2016)

2.1.3.2 Surface Waves

Surface waves, another type of wave in Seismic waves which travel free along the earth fee earth's surface . Frequencies surface waves are lower than body wave since it only through the crust .In the Surface waves, there are also two categories of waves, there are Love-waves and Rayleigh waves. The description is shown at below:

2.1.3.2 .1 Love-Waves

Love waves are similar to S waves. When the waves are travelling close to the ground surface, they are transverse shear waves. "They usually travel slightly faster than Rayleigh waves ,about 90% of the S waves and have the largest amplitude" (Hayes.K ,). L wave moves the ground side to another side and having a velocity which is 2 to 4.4 km/sec .

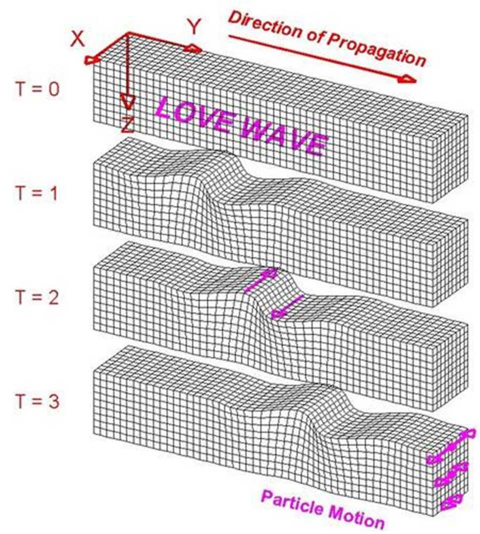


Figure 2.10: Love waves motion

Adopted from : (UPseis,2016)

2.1.3.2 .2 Rayleigh Waves

The Rayleigh wave are combination from P and S wave and moves the ground up and down and side to the another side in same direction of wave is moving .This type of wave is moving like the propagation of ocean waves because the biggest displacements of the particle at the surface. Rayleigh waves have the properties that dispersion, its wavelength keep changing and the velocity is not constant. So this type of wave is not stable in acceleration movement. (Ucl.ac.uk, n.d.)

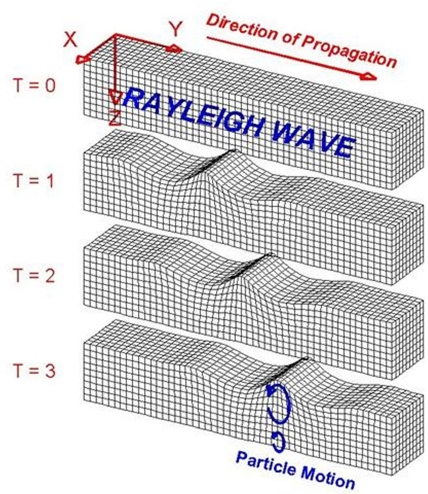


Figure 2.11: Rayleigh wave motion

Source : (UPseis,2016)

2.1.4 Characteristics of ground shaking

There are three most important characteristics of ground shaking which is peak ground acceleration , duration of shaking and the frequency of shaking . The highest acceleration recorded of damaging earthquake rangefrom 0.2g to over 1.0g where is g is the acceleration due to gravity . Very few building can resist such a large force . The higher the level of ground acceleration, the greater the horizontal earthquake forces induced within the building.

Earthquake acceleration are recorded inform of seismograph which record the rapidly changing accelerations or velocities throughout the duration of a quake . Mathematical manipulation of these records produces corresponding graphs of velocity and displacement against time (Fig. 1.12)(Norton J.A , 1994). shows a movement of 0.2 m in one direction and just over 0.3 m in the other in a period of approximately 1.5 seconds. An appreciation of the maximum inertia forces generated within buildings during this quake is gained from noting the far higher frequency accelerations from which the peak ground acceleration can be determined. The accelerations last for such small periods of time their displacements are smoothed out in the displacement-against-time graph.

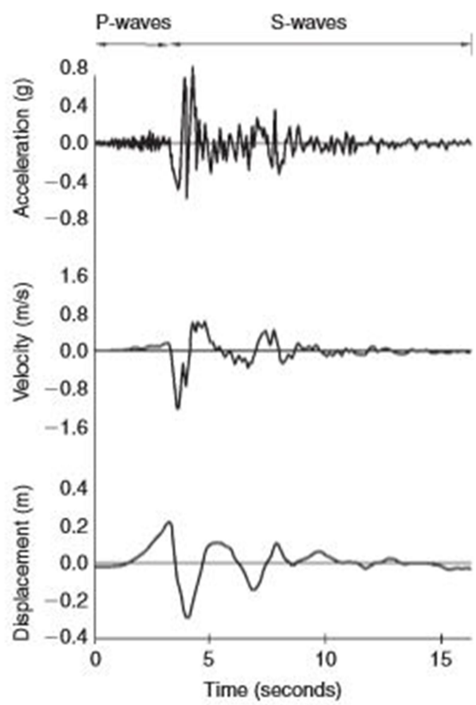


Figure 2.12: show the movement of 0.2 m in one direction.

Source**:** seismic design for architects (Charleson.A)

2.1.5 Measurement Of Earthquake

2.1.5.1 Magnitude

"Magnitude is quantitative measure of the actual size of the earthquake .Professor richter noticed (a) at the same distance , seismograms (records of earthquakes ground vibration) of larger earthquakes have bigger wave amplitude than those of smaller earthquake and (b) for a given earthquake , seismogram at farther distance have smaller wave amplitude than those at close distances. " (C.V.R Murty,2013)

2.1.5.2 How to measure earthquake magnitude

There are a number of ways to measure the magnitude of an earthquake. The first widely-used method, the **Richter scale**, was developed by Charles F. Richter in 1934. It used a formula based on amplitude of the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer. That scale was specific to California earthquakes; other scales, based on wave amplitudes and total earthquake duration, were developed for use in other situations and they were designed to be consistent with Richter's scale.

Beside richter scale , the are many magnitude scales such as body wave magnitude , surface wave magnitude and wave energy magnitude . These numerical magnitude scales have no upper and lower limits , the magnitude can be zero or negative . Magnitudes are based on a logarithmic scale (base 10), this means is that for each whole number you go up on the magnitude scale, the amplitude of the ground motion recorded by a seismograph goes up ten times. Using this scale, a magnitude 5 earthquake would result in ten times the level of ground shaking as a magnitude 4 earthquake (and 32 times as much energy would be released).

Table 1: *Global occurrence of earthquakes*

Group	Magnitude	Annual Average Number
Great	8 and higher	1
Major	7 – 7.9	18
Strong	6 – 6.9	120
Moderate	5 – 5.9	800
Light	4 – 4.9	6,200 (estimated)
Minor	3 – 3.9	49,000 (estimated)
Very Minor	< 3.0	M2-3: ~1,000/day; M1-2: ~8,000/day

Source: http::/neic.usgs.gov/neis/eqlists/eqstats.html

Figure 2.13: Magnitude

2.1.5.3 Intensity

“ Intensity is qualitative measure of the actual shaking at a location during an earthquake and is assigned as *Roman capital Numerals “* (C.V.R murty) . “Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment”(usgs)

The following table gives intensities that are typically observed at locations near the epicenter of earthquakes of different magnitudes:

Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 - 3.0	I
3.0 - 3.9	II - III
4.0 - 4.9	IV - V
5.0 - 5.9	VI - VII
6.0 - 6.9	VII - IX
7.0 and higher	VIII or higher

Figure 2.14 Intensity

Category	Effects	Richter Scale (approximate)
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8

Figure 2.15: Intensity with description

Source : (Dykstra.J ,2013)

2.1.6 Measuring Seismic Force

There are several definition in order to measure the effect of an earthquake to the ground :

I. Acceleration are measured in "g" s at 980 cm /sec² or 1.00g.
II. Velocity which is the rate of change displacement are measured in centimetres.
III. Duration is the length of time shock cycle persists.
IV. Magnitude of an earthquake measured by ricter scale

The longer the acceleration the less acceleration the building can endure . A building can resists very high acceleration but in short time only. Intensity is the amount of damage the earthquake causes locally, which can be characterized by Modified Mercalli Scale (MM). The damage are depending on distance of origin, local oil condition and type of construction

2.1.7 Seismic Effect on Structure

Building resting on it will experience motion at its base. From *Newton's First Law of Motion*, even though the base of the building moves with the ground, the roof has a tendency to stay in its original position. But since the walls and columns are connected to it, they drag the roof along with them .This tendency to continue to remain in the previous position is known as *inertia*. In the building, since the walls or columns are flexible, the motion of the roof is different from that of the ground.

- Structure will be damage if the faults breaks up to the surface but only structure directly on the fault will can be affected by its movement. Long linear structure such as viaducts and pipelines tendency to be affected compare to the building, because one part of them more likely to straddle a a fault break.
- The cyclic shear stress induced in the soil and may lead liquefaction (temporary loss of shear strength in loose , saturated, sandy soils) in soil .This can cause the failure of foundation.
- Coastal sites may need to consider tsunamis triggered by large offshore earthquakes. Many lives were lost in tsunami following the Indian Ocean earthquake of 2004 and Tohaku Japan earthquake of 2011 .A report by the National Tsunami Hazard Mitigation Program (NTHMP,2001)
- Fire following earthquake has cost many lives in the past (Scawthorn,2003)
- Lead to release noxious chemicals, flammable materials or radioactive materials.

2.2 SHELL STRUCTURE

"Shell structure, In building construction, a thin, curved plate structure shaped to transmit applied forces by compressive , tensile, and shear stresses that act in the plane of the surface" (Encyclopidia Britannica ,2016)

2.2.1 Early shell structure

Existence of shell structure is for many centuries. The earliest shell structure represent is domes which is to provide roofing for mosque temples, cathedrals, monument, etc.. "Notable historical examples include the Pantheon of ancient Rome, built around 2000 years ago , the Hagia Sophia of Constantinople (Istanbul), which is approximately 1500 years old ; St Peter's Cathedral in Rome ,a Renaissance structure whose dome , dating back about 1590 , was design by Michelanglo" (Zingoni.A ,shell structure ,1997)

Figure 2.16 : Hagia Sophia of Constantinople (Istanbul)

Adopted from: Spencer .R ,2015

2.2.2 Shell Application

As may be seen now , there are many modern shell application around us , among these are thin concrete shell roofs such as hyperbholic paraboloidal roof. Next , the application of shell not only for rofting but we also used in many other field such as storage , power station , water reservoir , off shore oil platform and etc ..”Shell may be defined as a relatively thin structural element, in which the material of the element is bound between two curved surface a relatively small distance apart “(Zingoni.A ,shell structure ,1997),

In Malaysia we can see the application of shell structure a widely use especially for administration buildings for example Perdana Putra, Putra Jaya. Beside that , dome also used for place of worship such as mosque and church . The number of worship places in Malaysia increase by year, and become the center of attraction.

Figure 2.17 : Perdana Putra , Putra Jaya used for administration buildings.

Adopted from : wikipedia

Figure 2.18 : Mosque ,Selangor Malaysia

Source: gettyimage.2015

2.2.3 Effects Of dome structural system

"The dome is a structural form, which distributes load to supports through a doubly curved plane ". Dome does not have corner or perpendicular change in surface direction since it is a continuous geometric form. It encloses the maximum volume with a minimum of surface area. The dome must be designed to resist compressive stresses along the meridian lines and to resolve circumferential tensile forces in the lower portion of hemispherical domes. The dome is an extremely stable structural form and resists lateral deformation through its geometry.

The dome structural system has major effects on the dynamic behavior and lateral load resisting mechanism of the structure. To know the good dome structures are system should be consists of proper load distribution and the load transfer are safe. To understanding the behavior of lateral system, several parameters must be considered such as shape of structure, size and thickness. Existence of proper buttress system, height/width ratio of the main arches, etc. The most important issue to be considered for a stable structural system is whether these parameters develop a proper horizontal diaphragm that ensure stable in plane movement with acceptable in-plane deformations or not.

The seismic forces in elastic region are dependent on the following factors:

i. intensity and frequency content of earthquake, and
ii. Dynamic characteristics of structure such as frequencies, mode shapes, and damping.

In inelastic region, some other factors also become influential such as the hysteresis behavior of members and connections, the amount and distribution pattern of strength within a structure, response modification factor, and ductility. Thus, in inelastic region, the shortage of strength with respect to elastic demand is compensated by the ability to sustain inelastic deformation, usually referred to as ductilit

2.2.4 Period of vibration

Type of motion:

i. Vibrate back and forth by considering cycling back and forth.
ii. Hold down both sides of the shear walls

Earthquake generate wave and travel in all direction up to the surface of the earth "

i. The wave consists of horizontal and vertical forces on buildings.
ii. Vertical force cause building move up and down.
iii. Horizontal force cause building move laterally and vibrate back and forth during an earthquake.

Period of vibration:

i. Period of vibration is time that object takes to vibrate back and forth in one complete cycle.

ii. Important things :

- Building do vibrate
- Undergo motion multiple times.

iii. Important factor to determine the respond of structure to the ground shaking .

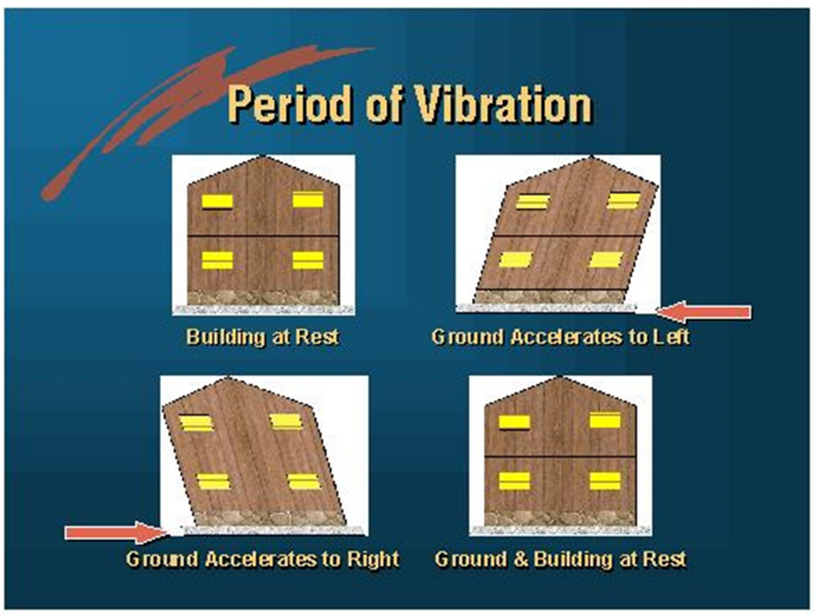


Figure 2.19: shows the motion of building when earthquake loading imposed

Source : http://www.abag.ca.gov/bayarea/eqmaps/fixit/ch2/sld012.htm

2.2.5 Factor affecting the severity of seismic forces

2.2.5.1 Building weight

To identify the inertia of the building the most important factor is determining the weight of building. Newton's Law states that inertia force is proportional to mass or weight. The greater the weight , the greater value of inertia and certain level of accelerations . In earthquake prone regions, we should therefore build as light-weight as practicable to reduce seismic vulnerability. As we know to construct a building we used heavy material such as brick , stones masonry , adobe and reinforced concrete , this type of material are used widely in construction So engineer and architect should always attempt to built a building more light .

2.2.5.2 Natural period of vibration

Hold a reasonably flexible architectural model of a building and give it a sharp horizontal push at roof level. Natural period of vibration is the time take for one full cycle measured in second . Every single of building has their own natural period of vibration. Natural period of vibration are depending the height of building

2.2.5. 3 Damping

Damping are used to reduce the magnitude of horizontal vibrations each successive cycle . The internal friction within the building element cause the amplitude of vibration of decay and produced damping . The degree of damping in a building depends upon the material of its seismic resisting structure as well as its other construction materials and details. Damping absorbs earthquake energy and reduces resonance or the build-up of earthquake inertia forces so it is very beneficial.

2.2.5.4 Response Spectrum

Response spectrum is a convenient method to illustrating and quantify the natural period of vibration and damping of a building affects its response to earthquake shaking. When the vibration occurs the maximum horizontal acceleration are recorded and plotted on a graph ,shown at figure 2.20. The shape of a response spectrum illustrates how the natural period of vibration of a building has a huge effect on the maximum horizontal acceleration experienced, and consequently upon the magnitude of inertia force it should be designed for. Maximum acceleration of the building at 0 natural period , although the shape of a particular response spectrum illustrates some of the fundamentals of seismic design it is not particularly useful for structural engineers.

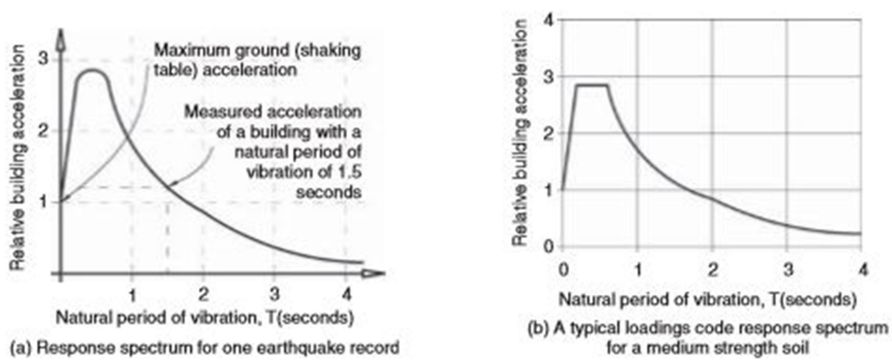


Figure 2.20: graph of response spectrum

2.2.5.5 Ductility

Ductility has a large influence upon the magnitude of accelerations and seismic forces a building is designed for, just like its natural period of vibration. Depending upon the degree of ductility a structure possesses the design seismic force can be reduced to approximately as little as one sixth of an equivalent non-ductile structure.
Ductility can be describe as opposite of brittleness which is when the non ductile material like glass is stretched and suddenly snaps because it reached elastic limit .

Ductile material will deform plastically after reached elastic limit . The strength of material will increase until the elongation occurs and break the material .

Ductility is one of the most desirable structural qualities of seismic resisting structures. If the intensity of earthquake shaking exceeds the strength of a brittle member – be it a beam or column – the member breaks suddenly, possibly leading to building collapse. But if the member is ductile, its material will yield, exhibiting plastic behaviour up to a relatively large deflection. In the process of being deformed plastically, a ductile member absorbs seismic energy that would otherwise lead to the building experiencing increased accelerations. Ductility therefore increases the effective level of damping in a building.

2.3 CONCLUSSION

Earthquake are the most disaster phenomena in the world , we cannot avoid nor predict the time of earthquake to happen .Malaysia are country does not suffer from direct earthquake damage however, significant long distance tremors were experienced which cause much concern to almost everybody . Study in earthquake are must to make sure citizen are prepare to faces these problem because we know that the tectonic plate are moving time by time . Full preparation should be exposed to avoid any problem in future . To the engineer , the study of earthquake are must to make sure the building are safe to use . There are several parameters should be consider before designing such as the maximum displacement , acceleration and velocity the building can resists during earthquake . Percentage of people die might be reduce during earthquake when proper design are propose. The building are should be the safety places to live during earthquake or not ,because study show the highest of people die during earthquake are caused by collapse of building . A public building such as government building , mosque , temple and church should be focusing more and should be design properly.

CHAPTER 3

RESEARCH METHODOLOGY

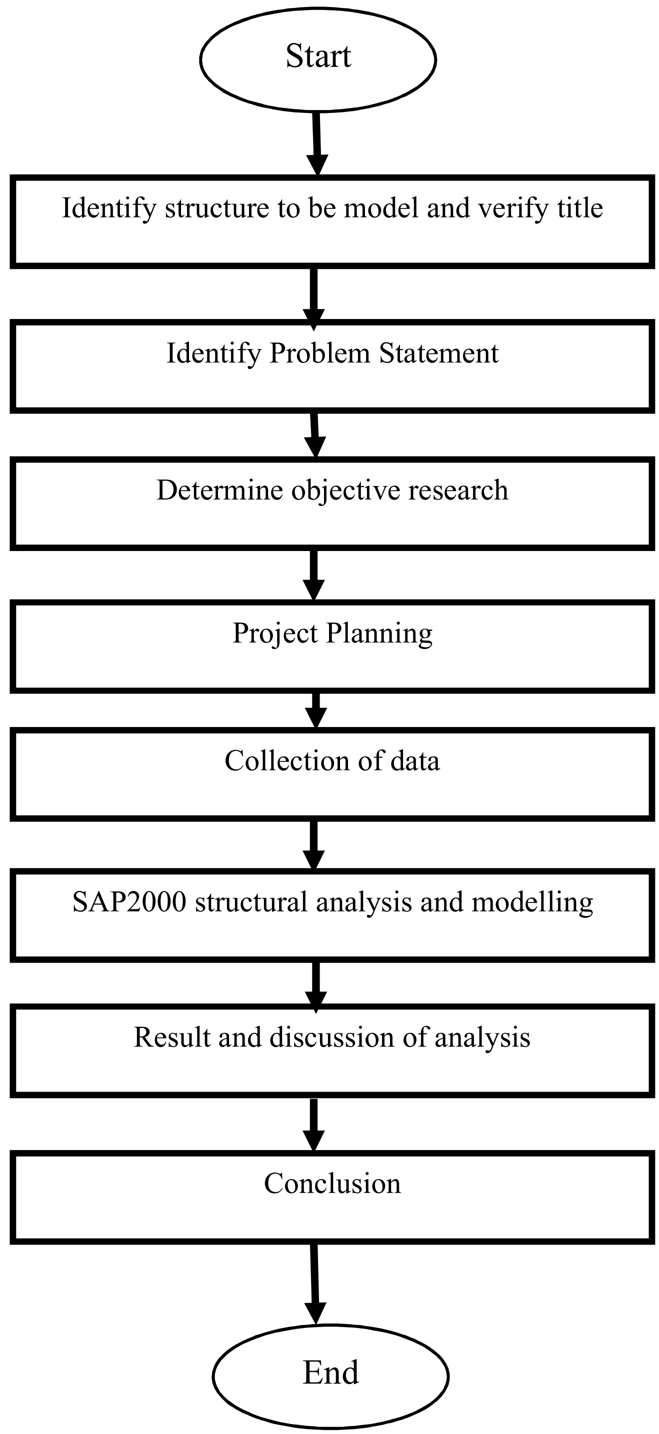
3.1 PLANNING OF THE STUDY

Planning of the study are investigate the best method to applied to a field of study . The problem statement should be identified and observed before deciding title of research project. Problem statement are conducted to identified and observed the problem and directly identify the solution, spherical dome structure are selected to be model in this research .The Analysis of the shell structure conducted by using SAP2000 software, which is study of acceleration, displacement and dynamic of the shell structure during earthquake.

Data used during conducting the project are time history earthquake data which is obtained from from Ache Indonesia , Bukit Tinggi and Philippine . Data are used from another country because Philippine and Indonesia are the nearest country with Malaysia and from the previous study show some of earthquake are also effecting Malaysia

SAP2000 as the tools to conducting the project , the analysis will show the behaviour of shell structure when the earthquake loading are imposed on structure .

FLOW CHART OF THE METHODOLOGY



3.2 LITERATURE REVIEW

The most important phase during process in the making of thesis is literature review because all the information , knowledge, info , evidence related to the research are collected. These chapter will explained either the literature review are supported or not .To identify the literature review either they are correct or not , supported evidence should be conducted

The data collection should be conducted during at these phase . Type of data should be gain before conducted the analysis such as time history, size and dimension of the shell structure , effect of concrete structure during earthquake and SAP2000.

Source of literature review are from journal, education book , magazine , online news , and article related to the impact of shell structure in earthquake . The most sources are collected from books such as earthquake engineering , shell structure and hazard of earthquake .

3.3 DATA COLLECTION

The data collection :

i) Domed structure data common dimension

ii)Earthquake data

The data should be prepared before the analysis for modeling and analysis conducted such as the height of structure , thickness , length ,etc

3.3.1 Loading

The analysis will consist of several loads such as live and dead load and earthquake load.

3.3.1.1 Dead and Live load

Dead load and live load are determine , live load are including selfweight structure.

3.3.1.2 Earthquake data

Earthquake data obtained from Indonesia , Philippine and Bukit Tinggi .

3.4 ANALYSIS

The research conducted by using several load , such as live and dead load , earthquake load , etc . The analysis will be consisting of:

1) Determining acceleration and displacement of shell structure due to the earthquake.
2) The shape of structure with different loading.

SAP2000 will analyse the structure by inserting all load involve and Time Historydat. The deformation of shell structure can be analysed and force in shell and joint observe.

3.5 SAP 2000

SAP Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code.

From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, SAP2000 is the easiest, most productive solution for your structural analysis and design needs.

SAP2000 computer software is a stand-alone-finite-element-based structural program for analysis and design of civil structure. The specification are powerful user interface and provide many tools, it will make work more fast and accurate construction of models.

The software is objecting based which is model are created with members that represent the physical reality. Easy to interpret the results of analysis and report for overall object.

Shell structure can be analysed by using SAP2000,there consists several shaped of shell structure are provided, such as dome, spherical dome, cylindrical ,etc.. Research only cover for spherical dome structure.

3.4.1 STEP in SAP2000 Computer Software

Step 1 : Define the model type

Research are analysed shells structure, choose shells Template

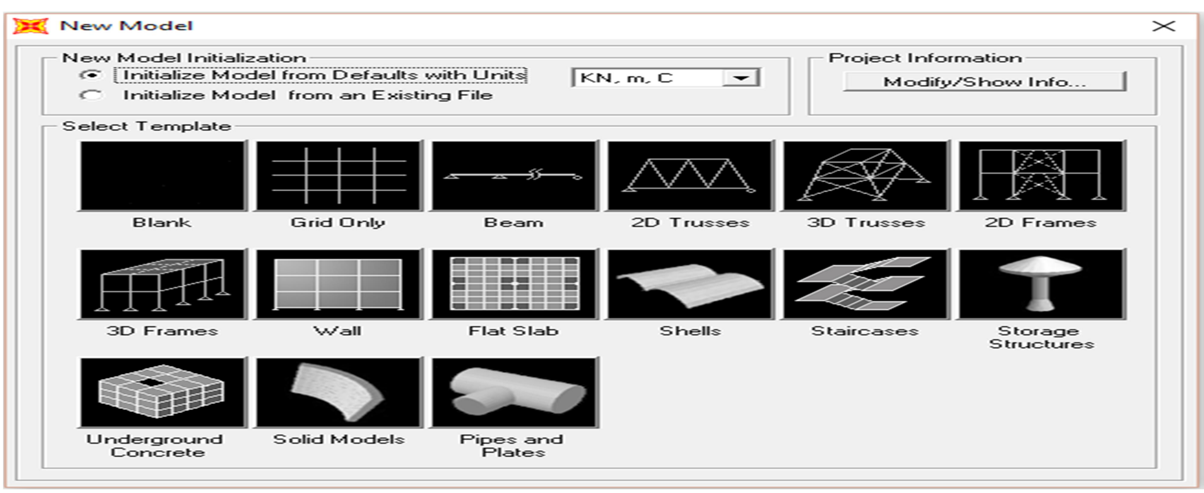


Figure 3.1: Template model SAP2000

Step 2: Choose type of of shell

Select shell type , type of shell is spherical domed. Insert the value of radius, number of division, roll down angle and number of division

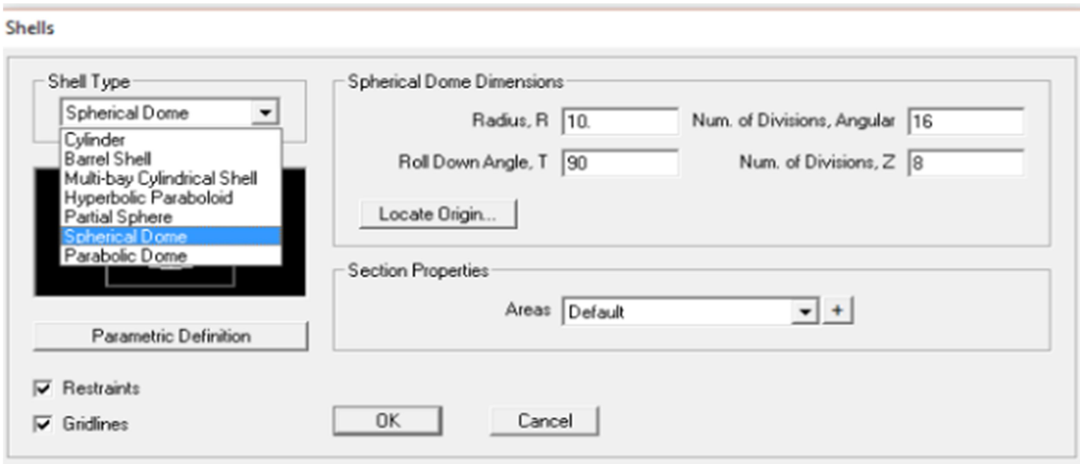


Figure 3.2 : Choosing shell type

Step 3 : Insert area of section

Add area section by click "+" at the section properties, after click "+" pop out will be in figure 3.3 .Click add new section

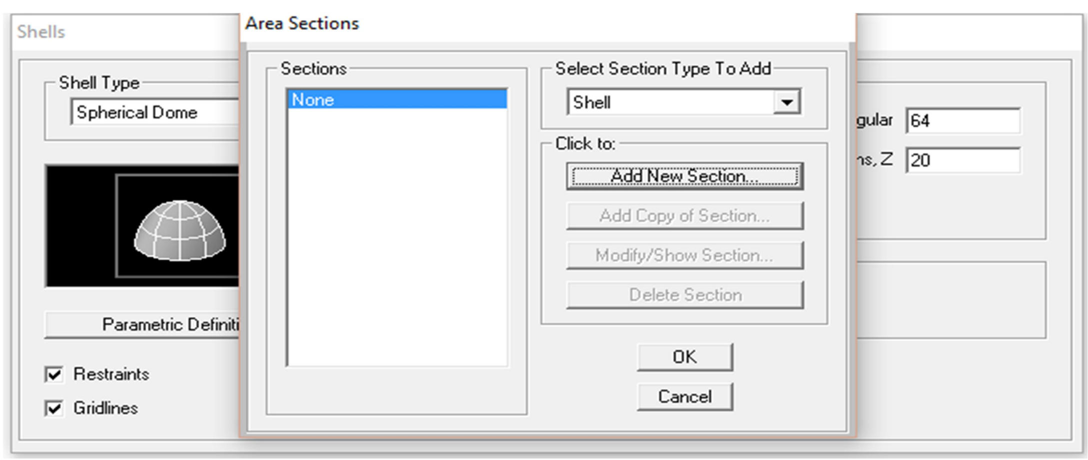


Figure 3.3: Determine the area section

Step 4: Editing section of data

Edit the section name and to modify colour click display colour and choose. To edit the detailed of material click material name.

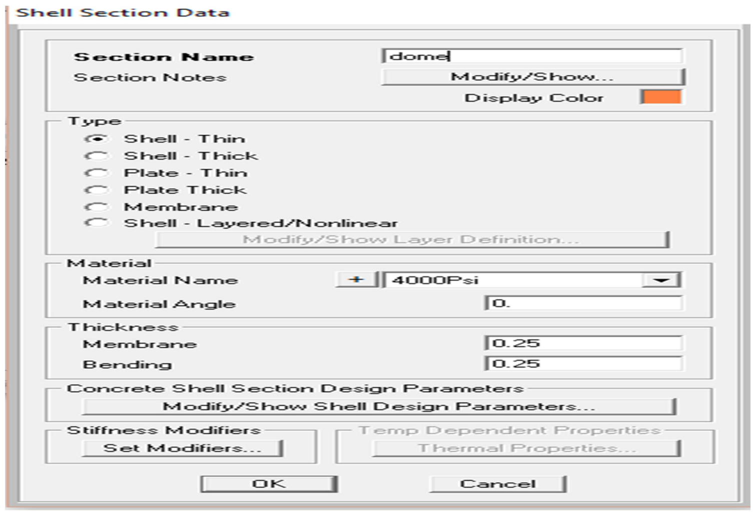


Figure3.4: Shell section data

Step 5 : Modify the material

Modified material by click “modify/show Material” and change the data according to specification of the structure and click “OK” , until no more pop out .

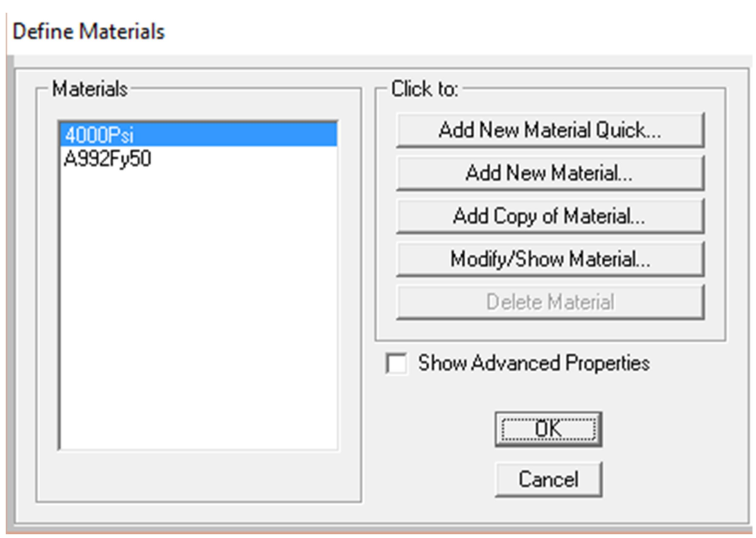


Figure3.5 : Define Material

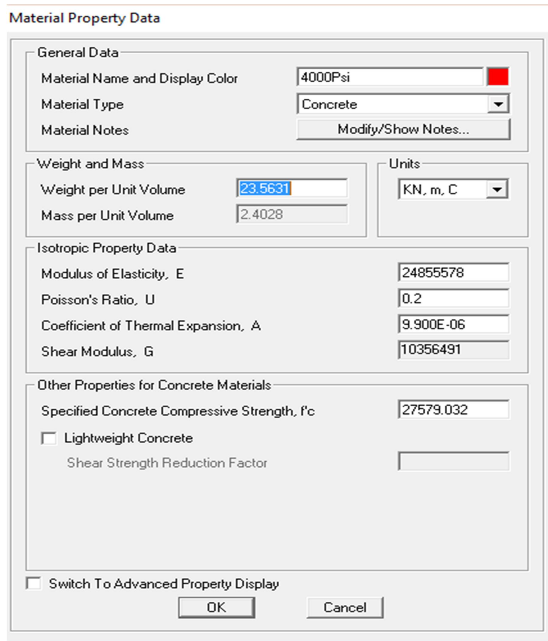


Figure 3.6 : Material Property Data

Step 6 : Generate the model

The model are generated follow the data insert .

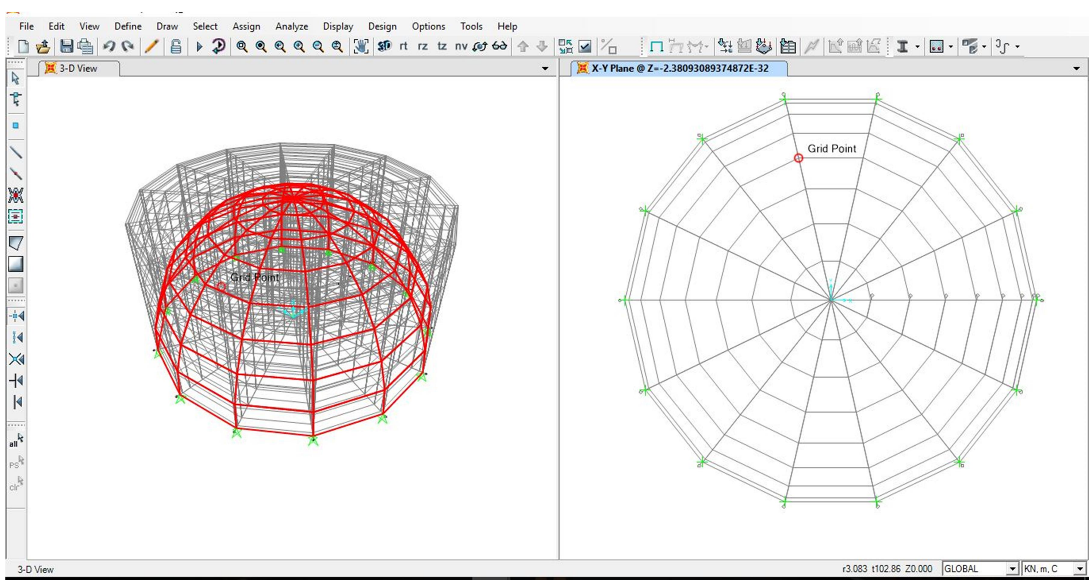


Figure 3.7 Shell Grid

Step7: Inserting load pattern

Insert load patterns , select "Define" , "Load Patterns" . To add new load pattern type the name of new load pattern at box "Load pattern name" ,select "type" , "set wight multiple" and click "modify Load pattern"

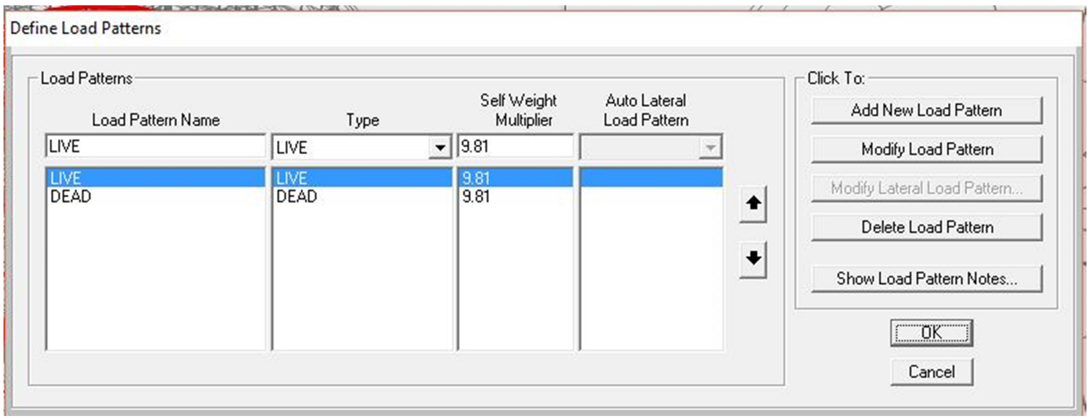


Figure 3.8 : Adding new load Pattern

Step 9 : Insert Time History

Insert time history , by selecting "define" at menu bar , next followed by "Function" and "time History".

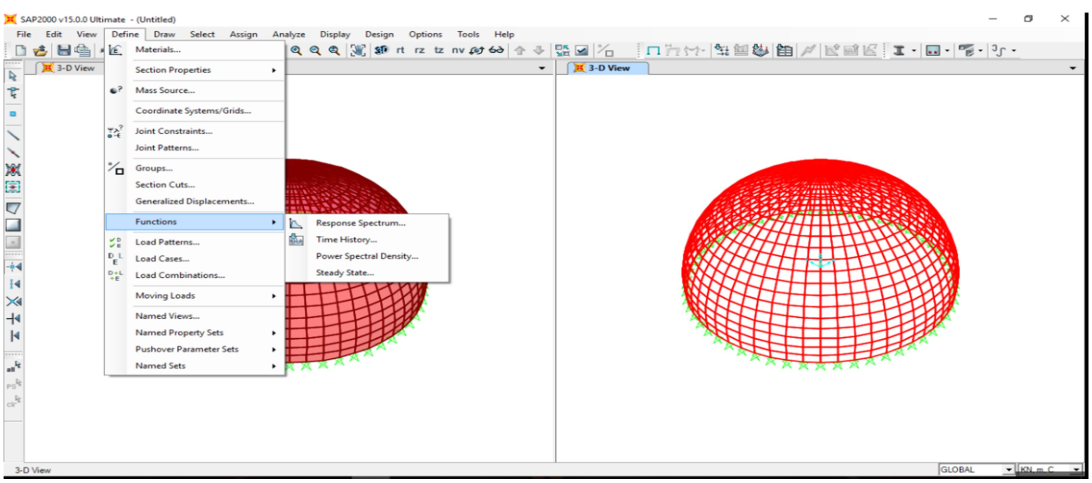


Figure 3.9 Inserting time history

Step 10: Import Time history

Add a new function , by select "choose Function Type to add" menu and select "From File" and click "add new" . To insert function click "browse" to browse the file and "display graph" and click "OK"

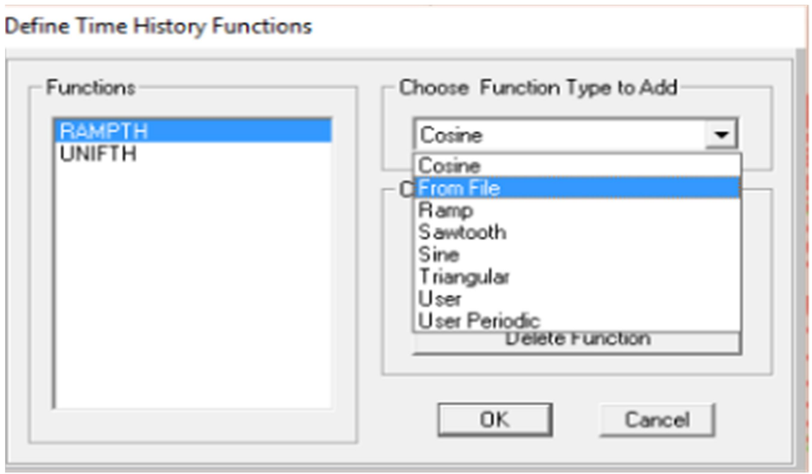


Figure 3.10: Add new file to time history function

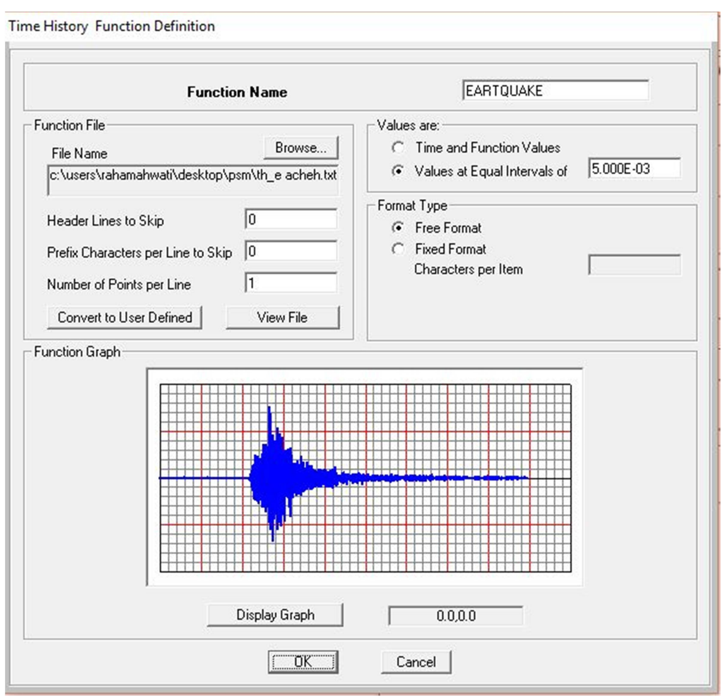


Figure 3.11: Time history

Step 10: Define Load cases

Define load cases , time history are added by clicking add new load case , there 2 type of load which is U1 and U2 and the scale factor is 9.81

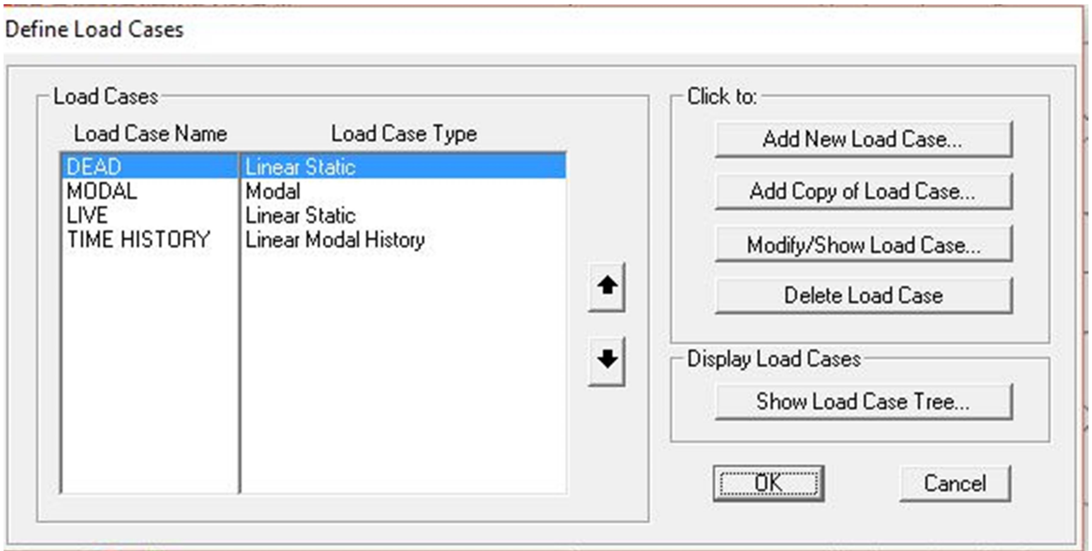


Figure 3.12: Define load cases

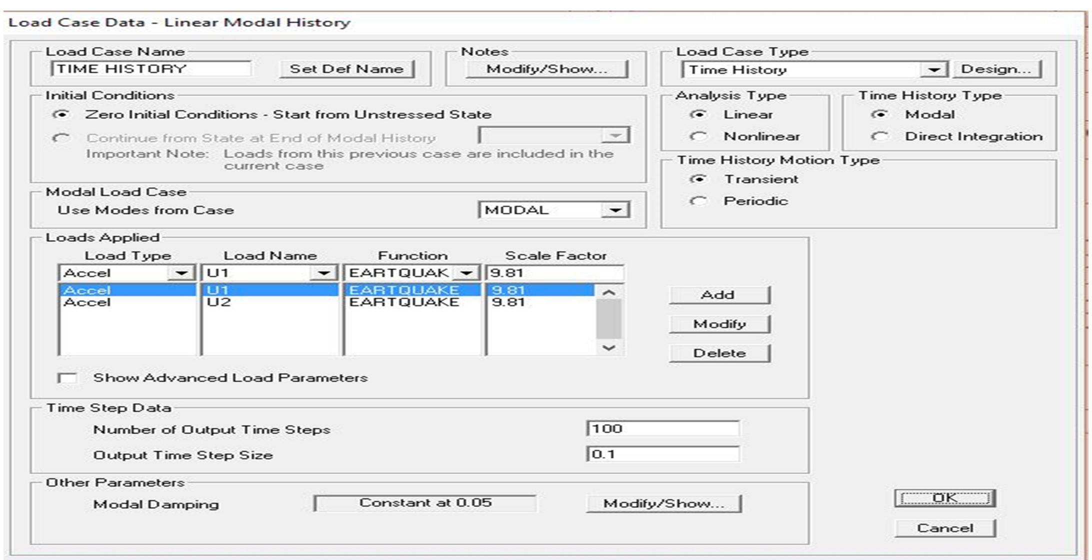


Figure 3.13: Load cases data

Step 11 : Analysed the project

To start analysed the project , load case should be define . To load cases click "Analyze", and choose set load cases to run . After clicking "run now " we can see the different shape of structure .

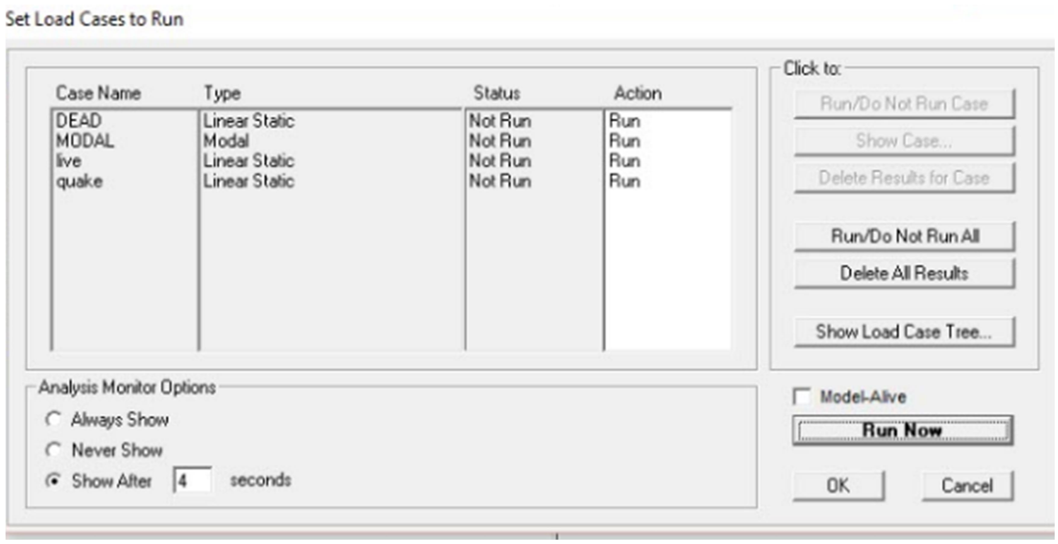


Figure 3.14: Set load cases cases to run

3.5 CONCLUSSION

The conclusion is, SAP 2000 can be used to analysed the structure especially it can analysed when horizontal force are hit the building. SAP2000 are user friendly and easy to used and easy to understand. Sap2000 are very recommended software to analysed the structure. The analysis are consists of dome structure which is the dimension of dome structure are common used in Malaysia. The time history used by the analysis is time history from ache Indonesia.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter represent the analysis of dome structure under earthquake loading . Earthquake loading that imposed to the structure are time history from acheh earthquake but receiver in Malaysia. Euro Code or seismic code check are not consider in this analysis.

4.2 ANALYSIS OF SPHERICAL DOME STRUCTURE

There are 3 type of loads are imposed to spherical dome structure which is , dead load , live load and earthquake .Software used are SAP2000 to analysis the behaviour of spherical dome structure under t earthquake loading .

By using SAP2000 contains 3 combination load cases that will be carry out in this analysis, which are:

i) Modal analysis
ii) Dead Load + Live Load
iii) Dead Load +Live Load +Earthquake

4.2.1 Modal analysis

Modal analysis or free vibration has been carried out by using SAP 2000 software. Modal analysis is the structure with the motion when no of external forces or support motion on it, which is tendency of spherical dome will tendency to happened when any force will imposed on it . The structure which is spherical dome will be move away from its equilibrium position because of the modal analysis.

The summary of the results has been tabulated in Table 4.1. Frequency and period of each mode shape are recorded, where the vibration of building will occurs when the existing of frequency from the ground and transfer to the structure .Beside that, figure 4.1,4.2,4.3,4.4,4.5 and 4.6 show the structure will vibrate in free option and the same shape tends dominate the motion of the structure during earthquake .This is showing that earthquakes bring frequency to the earth and will making the ground vibrate. The modal shapes which will be vibrating which have been assumed are properties of the system and this can be decisive empirically by using Modal Analysis.

By understanding the modes of vibration , it will help to easier and better design structure to withstand when earthquake force are attacked .From the modal analysis or free vibration analysis, will obtain of the natural period, 12 mode shape of dome structure, natural frequency, circ frequency and lastly is eigenvalue. Each of the mode shape of dome structure produce different of the natural period, natural frequency, circ frequency and lastly is eigenvalue.

The figure show all of 12 mode shape shell structure when the earthquake from acheh are imposed:

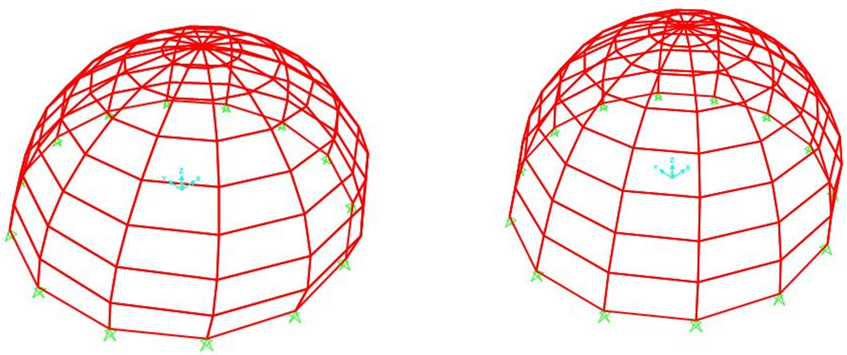


Figure 4.1 : Mode shape 1 with period of 0.01417 and Mode shape 2 with period 0.01417

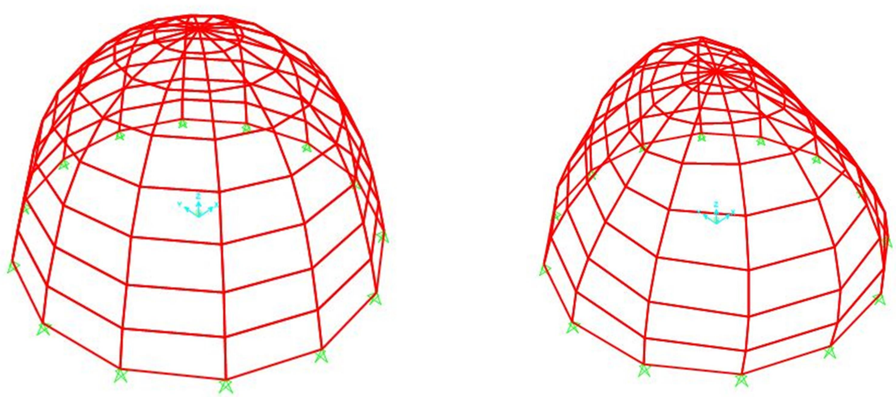


Figure 4.2: Mode shape 3 with period of 0.01065 and Mode shape 4 with period 0.00912

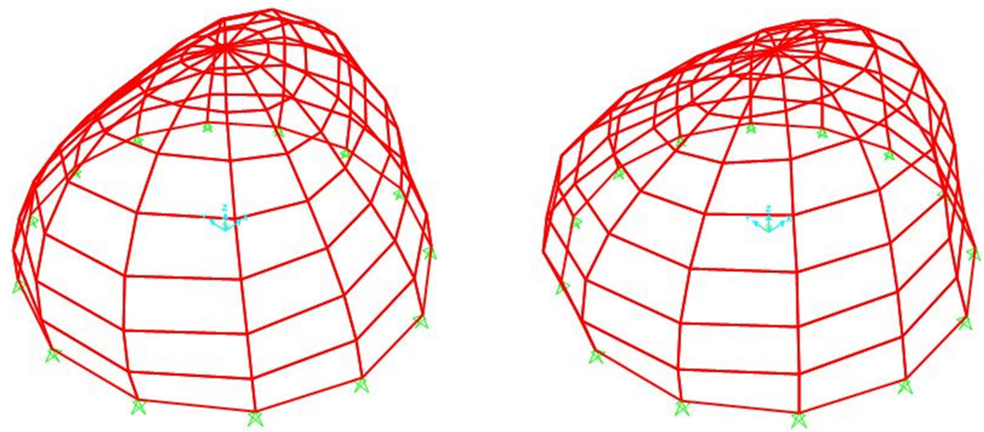


Figure 4.3: Mode shape 5 with period of 0.00912 and Mode shape 6 with period 0.00895

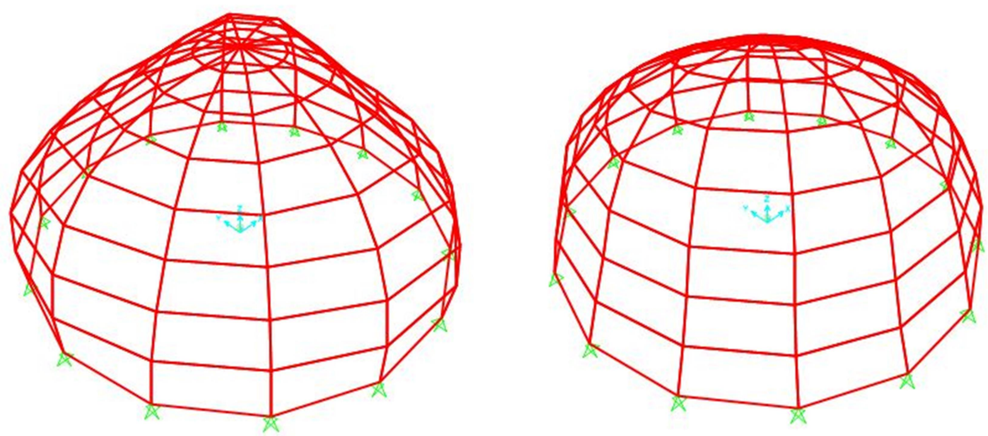


Figure 4.4: Mode shape 7 with period of 0.00933 and Mode shape 2 with period 0.00879

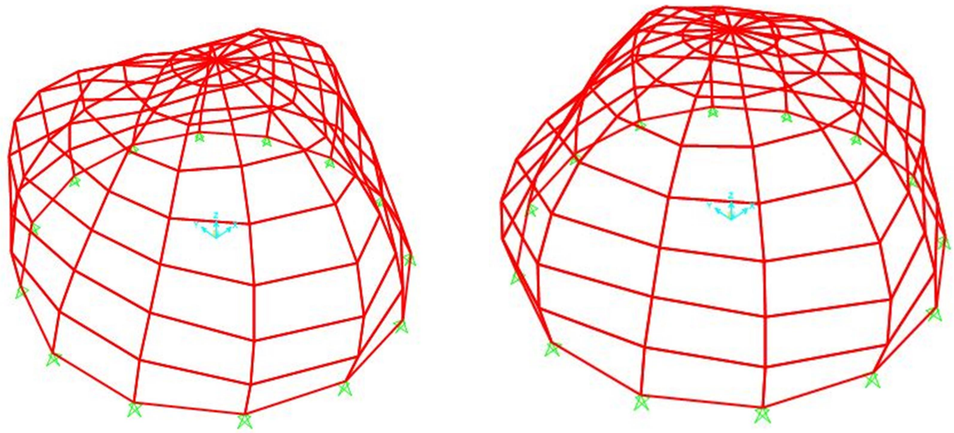


Figure 4.5: Mode shape 9 with period of 0.00879 and Mode shape 10 with period 0.00866

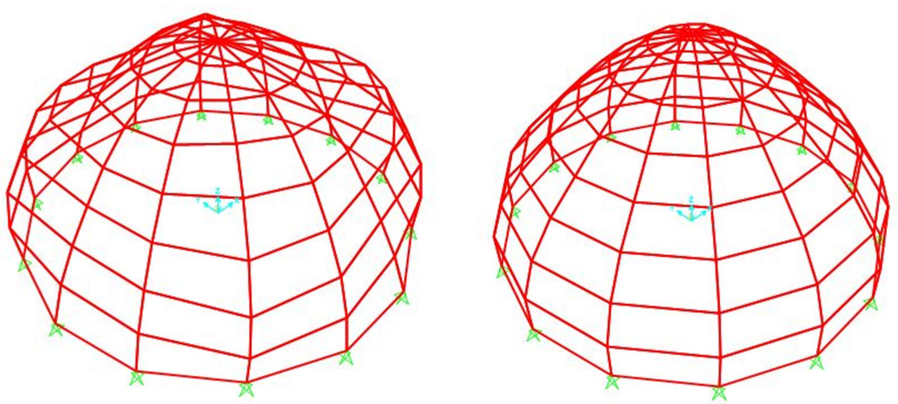


Figure 4.6: Mode shape 11 with period of 0.00866and Mode shape 12 with period 0.00852

Table 4.1: The result of free vibration analysis

Mode	Natural period , T (sec)	Natural frequency ,f (Hz)
1	0.014701	68.02
2	0.014701	68.02
3	0.011072	90.318
4	0.009407	106.3
5	0.009407	106.3
6	0.009333	107.14
7	0.009333	107.14
8	0.008983	111.32
9	0.008983	111.32
10	0.008899	112.38
11	0.008775	113.96
12	0.008775	113.96

From modal analysis, Mode shape 1 and 2 have the highest time period which is 0.014701 sec and the natural of frequency 68.02/sec, Mode shape 3 have the second highest time period which is 0.011072 sec and the natural of frequency is 90.318/sec and Mode shape 4 have the third highest time period which is 0.009407 sec and the natural of frequency is 106.3 /sec. This is showing that the first three of the mode shape is the best mode shape among of twelve mode shape because the highest of period and the lowest of frequency. Frequency also can be calculated by using formula of:

$$\text{Frequency}=\frac{1}{period} \qquad (4.1)$$

Since mode 1 the period is 0.014701 sec , frequency for mode shape 1 can be calculated as below:

$$\text{Frequency}=\frac{1}{0.014701} \qquad (4.2)$$

Frequency = 68.02/sec

4.3 DISPLACEMENT

“Displacement is the difference between the initial position of a reference point and any later position. The amount any point affected by an earthquake has moved from where it was before the earthquake”(USGS) . During earthquake occur, the structure will undergoes inertia .When the base of the building suddenly moves to the right, than the building will move to the left relative the base. These process are complex since the ground moves simultaneously in three mutually perpendicular direction during earthquake occur

Figure below show the several displacement will occur during earthquake attack :

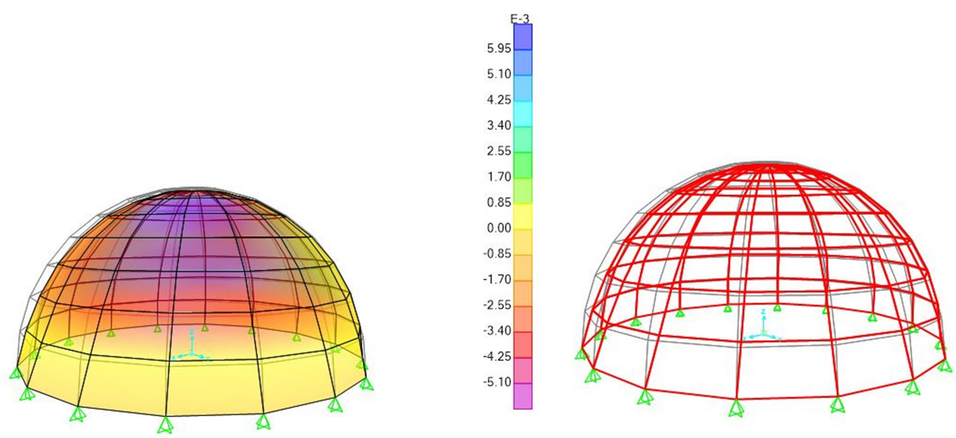


Figure 4.7: the figure show mode shape 1 , which is the minimum displacement is 0.109 and maximum displacement is 0

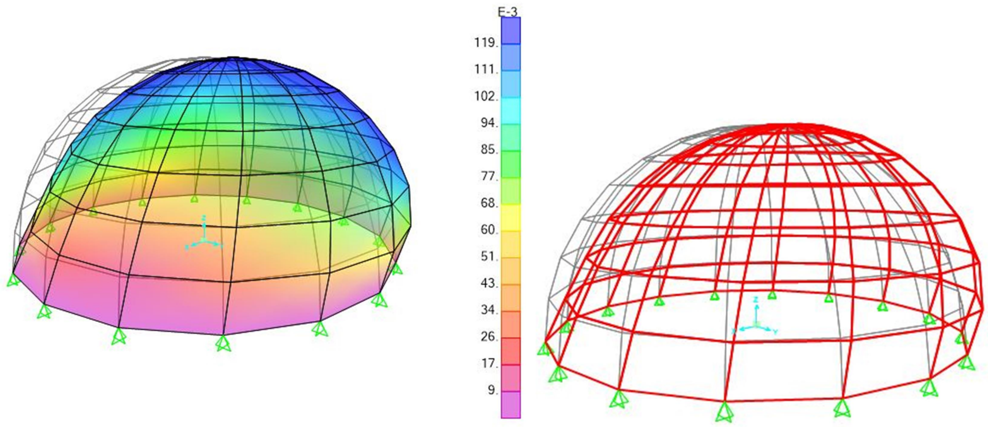


Figure 4.8: The figure show mode shape 2 , which is the minimum displacement is 0 and maximum displacement is 0.126

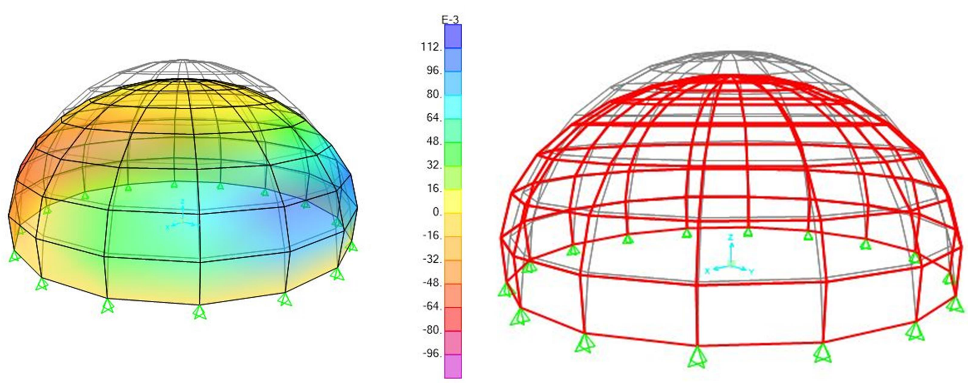


Figure 4.9: the figure show mode shape 3 , which is the minimum displacement is 0.127 and maximum displacement is 0.127

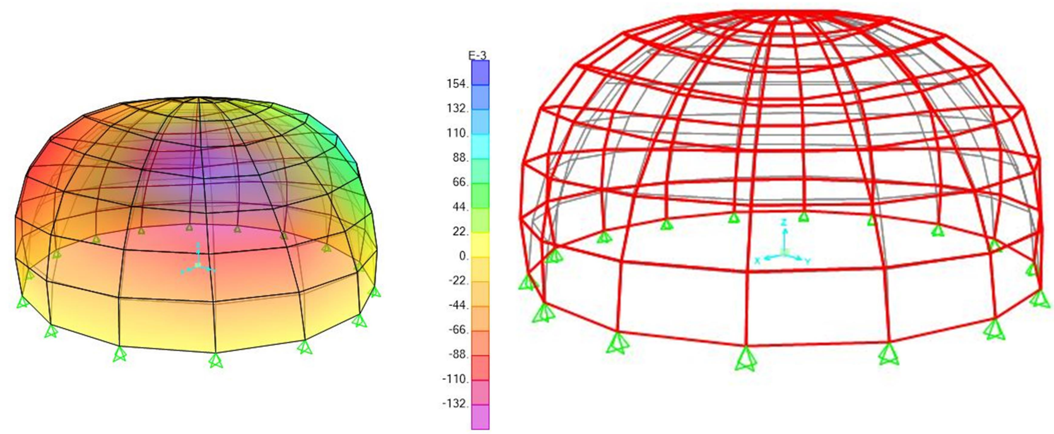


Figure 4.10: the figure show mode shape 4 , which is the minimum displacement is 0.144 and maximum displacement is 0.144

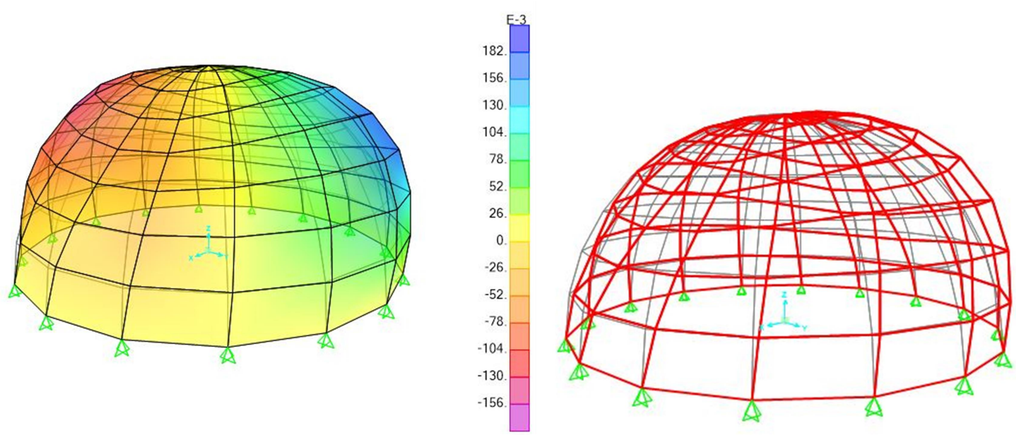


Figure 4.11: the figure show mode shape 5 , which is the minimum displacement is 0.177 and maximum displacement is 0.177

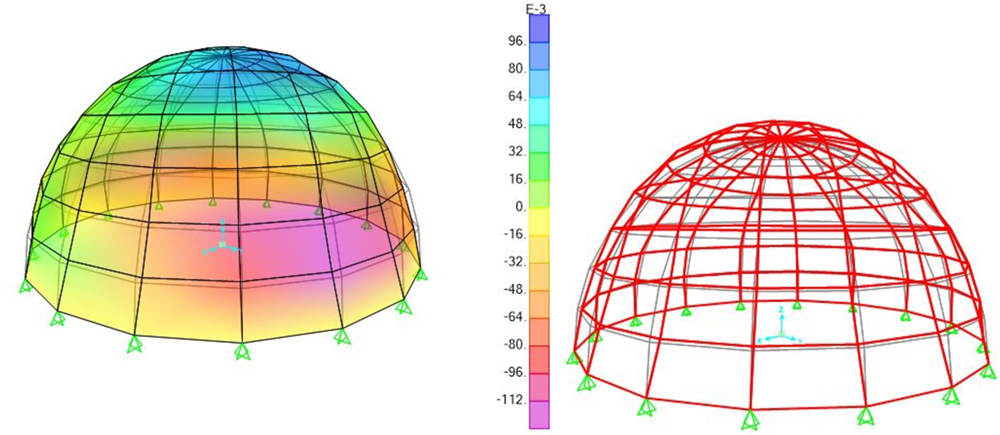


Figure 4.12: the figure show mode shape 6 , which is the minimum displacement is 0.127 and maximum displacement is 0.096

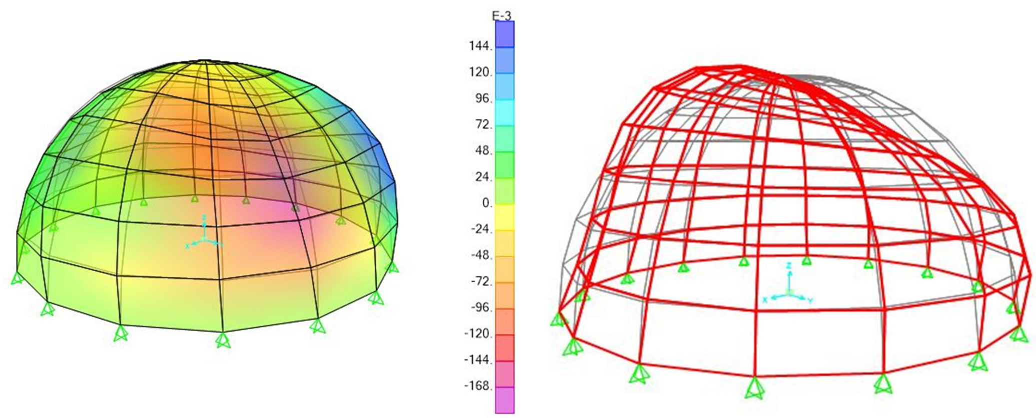


Figure 4.13: the figure show mode shape 7 , which is the minimum displacement is 0.092 and maximum displacement is 0.127

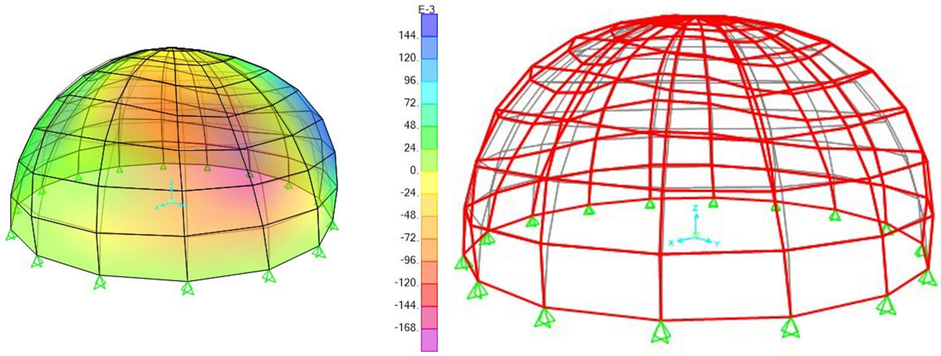


Figure 4.14: the figure show mode shape 8 , which is the minimum displacement is 0.177 and maximum displacement is 0.144

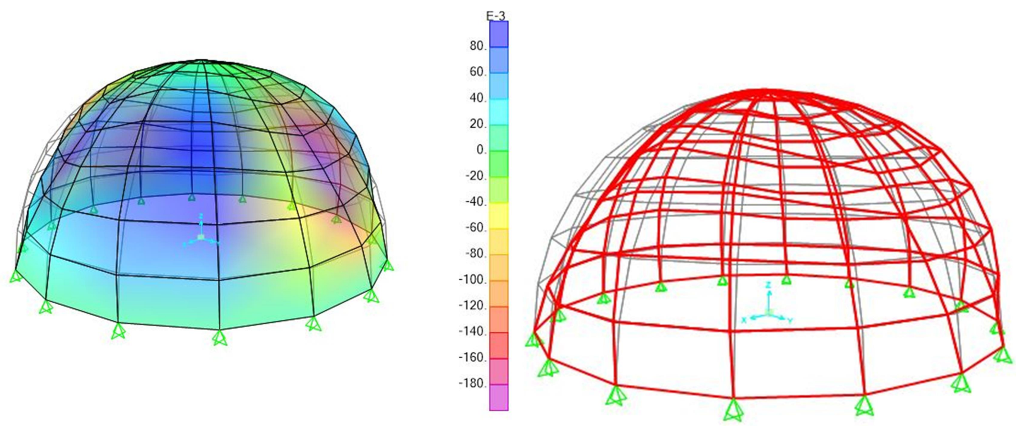


Figure 4.15: the figure show mode shape 9 , which is the minimum displacement is 0.197 and maximum displacement is 0.096

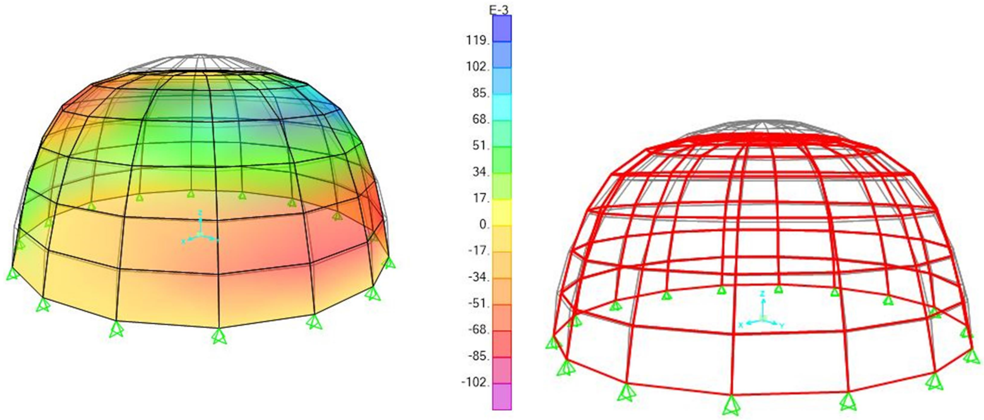


Figure 4.16: the figure show mode shape 10 , which is the minimum displacement is 0.113 and maximum displacement is 0.113

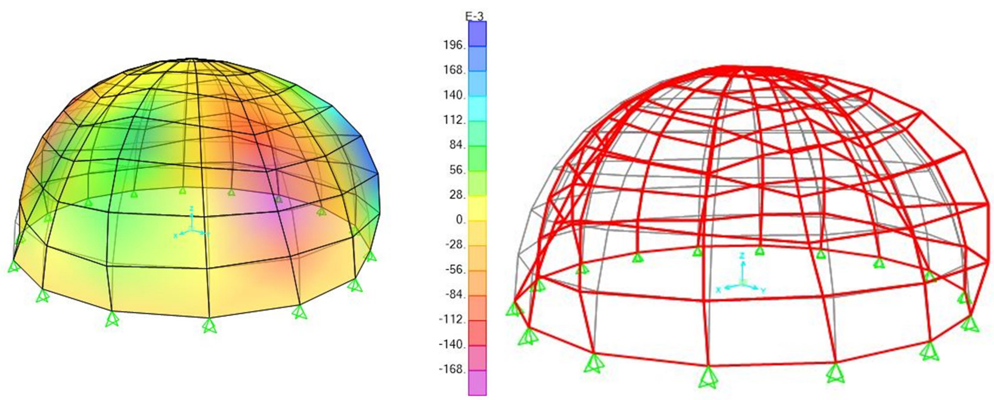


Figure 4.17: the figure show mode shape 11 , which is the minimum displacement is 0.187 and maximum displacement is 0.187

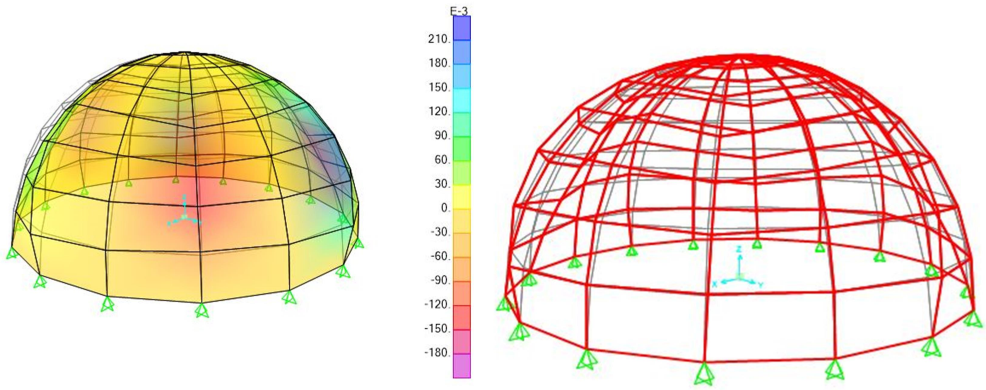


Figure 4.18: the figure show mode shape 12 , which is the minimum displacement is 0.199 and maximum displacement is 0.199

Mode shapes describe the configurations into which a structure will naturally displace. Typically, lateral displacement patterns are of primary concern. Mode shapes of low-order mathematical expression tend to provide the greatest contribution to structural response. As orders increase, mode shapes contribute less, and are predicted less reliably. It is reasonable to truncate analysis when the number of mode shapes is sufficient.

The important things, maximum and minimum displacement should be identify during designing the project. The maximum of displacement will be consider in the design .

4.3.1 Displacement of dome under earthquake loading

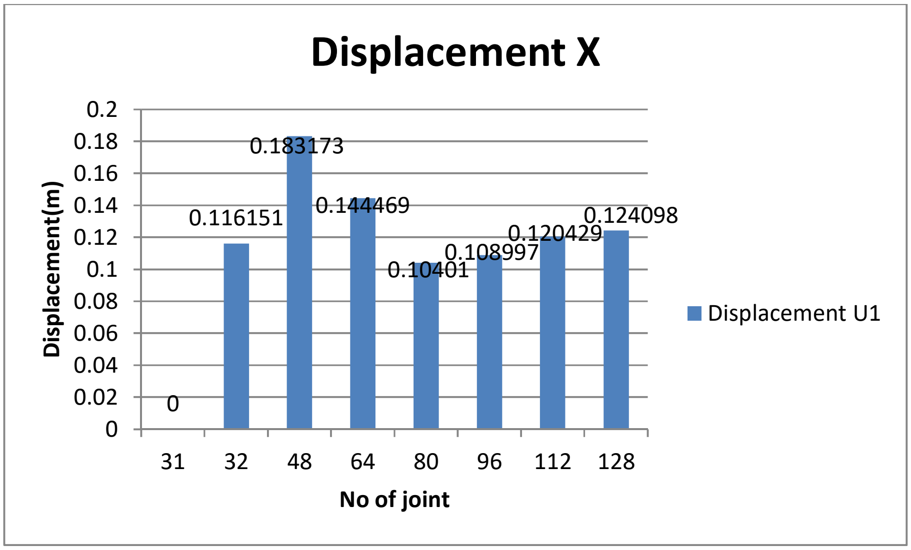


Figure 4.19: show bar chart displacement against no of joint

Figure 4.19 shows the displacement of joint at axis U which is U is indicate axis X. From the bar chart , the highest displacement occur at joint 48 which is 0.183173 m and displacement at joint 64 is 0.1444469 m where is the second highest among the joint . Joint 128 the third highest with 0.124098 m the value of displacement and joint 31 are 0 m. The displacements are occurring when the time history is added into simulation.

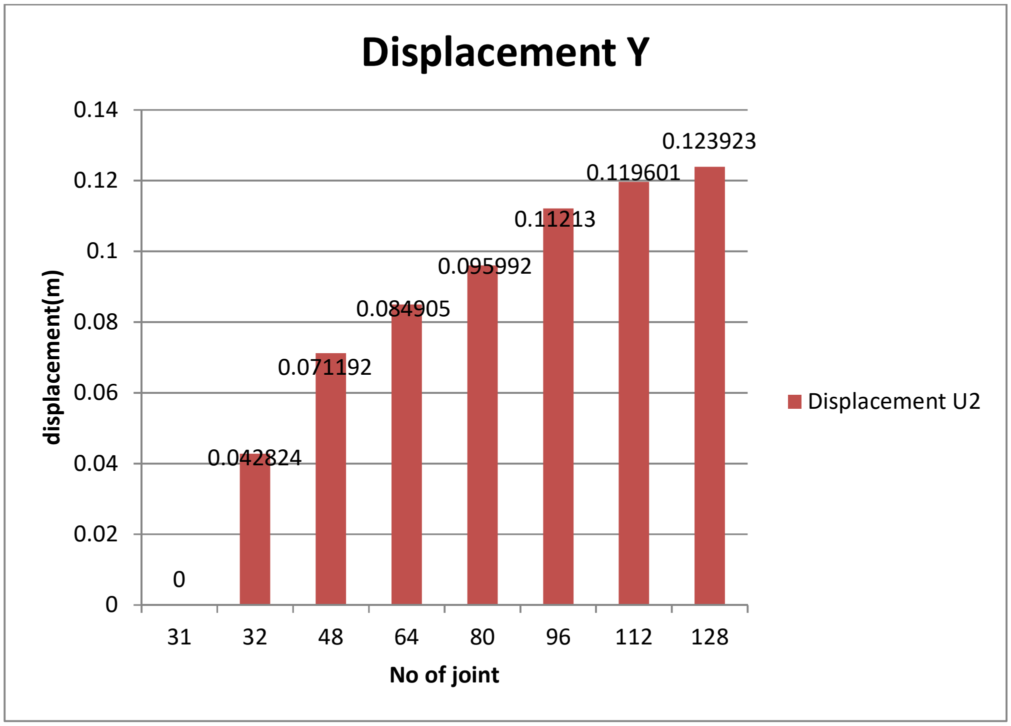


Figure 4.20: show bar chart displacement against no of joint

Figure 4.20 shows the displacement of joint at axis U2 which is U is indicate axis Z . From the bar chart , the highest displacement occur at joint 128 which is 0.123923 m and displacement at joint 112 is 0.119601 m where is the second highest among the joint . Joint 96 the third highest with 0.11213 m the value of displacement and joint 31 are 0 m. The displacement are occur when the time history are added into simulation.

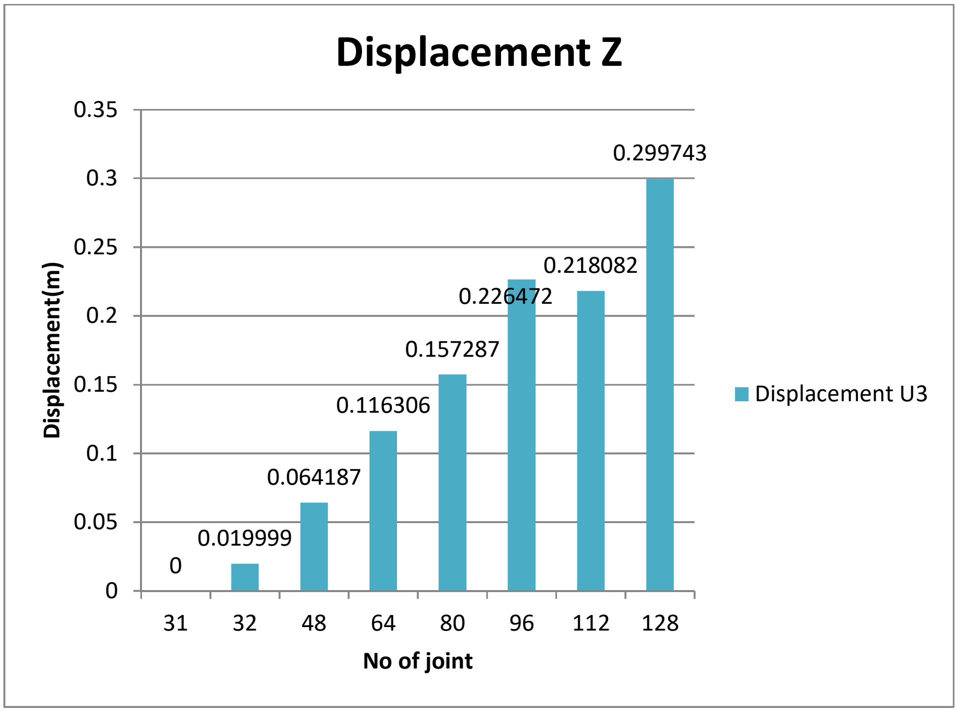


Figure 4.21: show bar chart displacement against no of joint

Figure 4.21 shows the displacement of joint at axis U3 which is U is indicate axis Y . From the bar chart , the highest displacement occur at joint 128 which is 0.299743 m and displacement at joint 96 is 0.226472 m where is the second highest among the joint . Joint 112 the third highest with 0.218082 m the value of displacement and joint 31 are 0 m. The displacement is occurring when the time history is added into simulation.

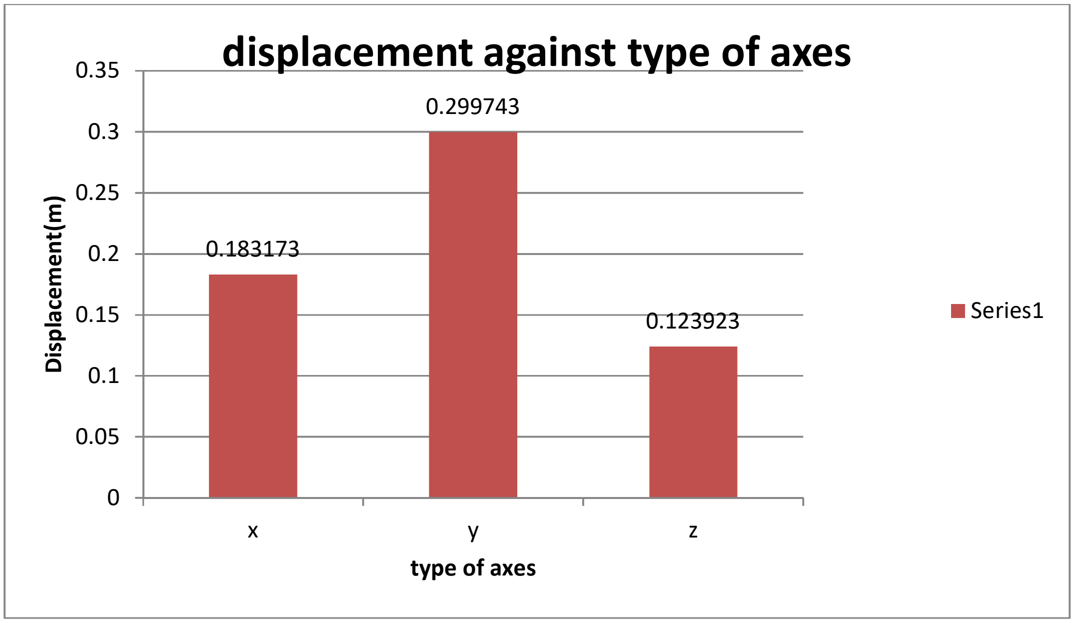


Figure 4.22: show bar chart displacement against type of axis

Figure 4.22 shows the maximum displacement at each axis X,Y and Z . The highest displacement occur at axes U3 which is indicated axis Y with 0.299743 m . Second highest average of displacement is X axis with value of displacement is 0.183173 and followed by axis Z with the value of displacement is 0.123923 m .

4.4 ACCELERATION

4.4.1 Acceleration of dome under earthquake loading

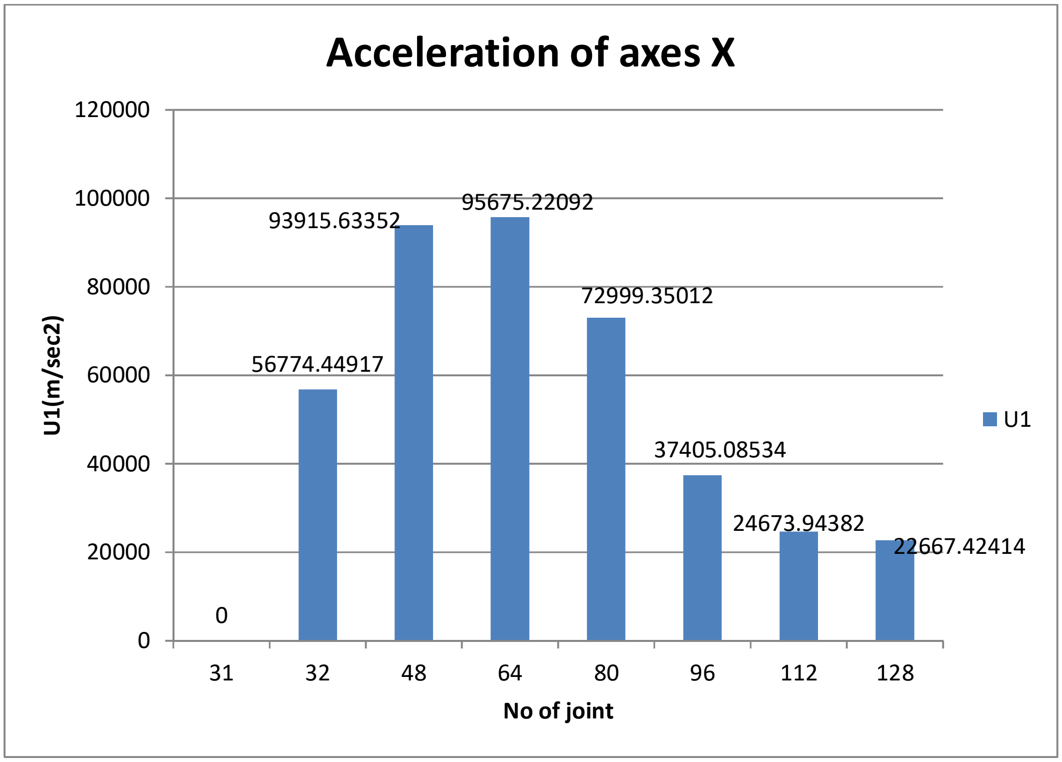


Figure 4.23: Bar chart no of joint against acceleration of axis U1**.**

Figure 4.23 shows the acceleration of joint at axis U which is U is indicate axis X . From the bar chart , the highest acceleration occur at joint 64 which is 95672.22092 m/sec2 and acceleration at joint 48 is 93915.63352 m/sec2 where is the second highest among the joint . Joint 80 the third highest with 72999.35012 m/sec2 the value of acceleration and joint 31 are 0 m. The acceleration are occur when the time history are added into simulation.

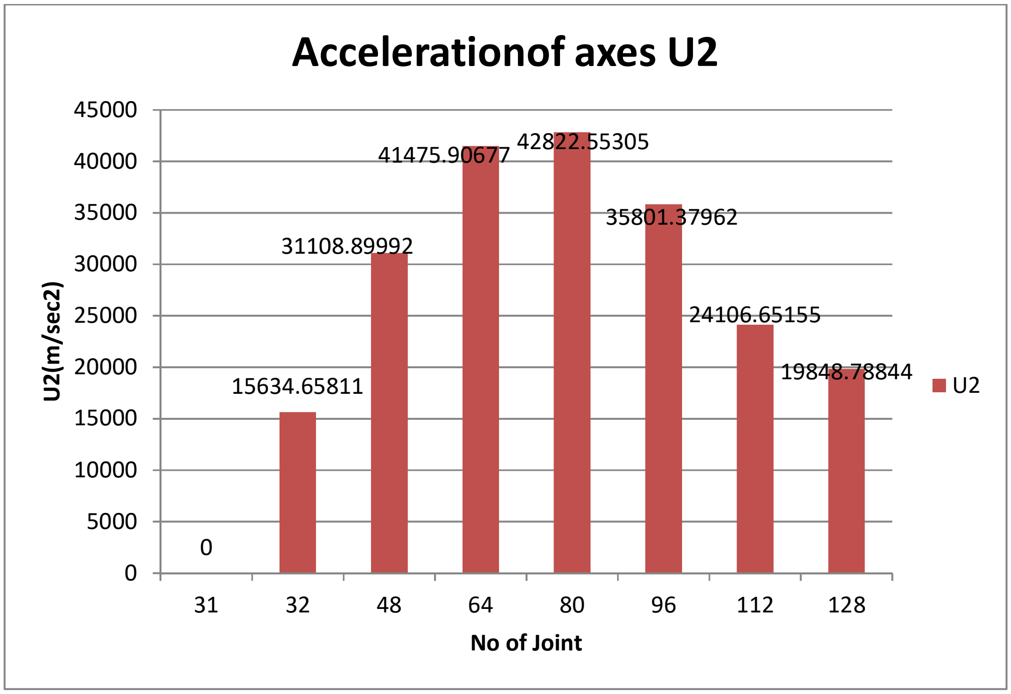


Figure 4.24: Chart no of joint against acceleration of axis U2**.**

Figure 4.24 shows the acceleration of joint at axis U which is U is indicate axis Z . From the bar chart , the highest acceleration occur at joint 80 which is 42822.55305 m/sec2 and acceleration at joint 64 is 41475.9067 m/sec2 where is the second highest among the joint . Joint 96 the third highest with 35801.37962 m/sec2 the value of acceleration and joint 31 are 0 m. The acceleration are occur when the time history are added into simulation.

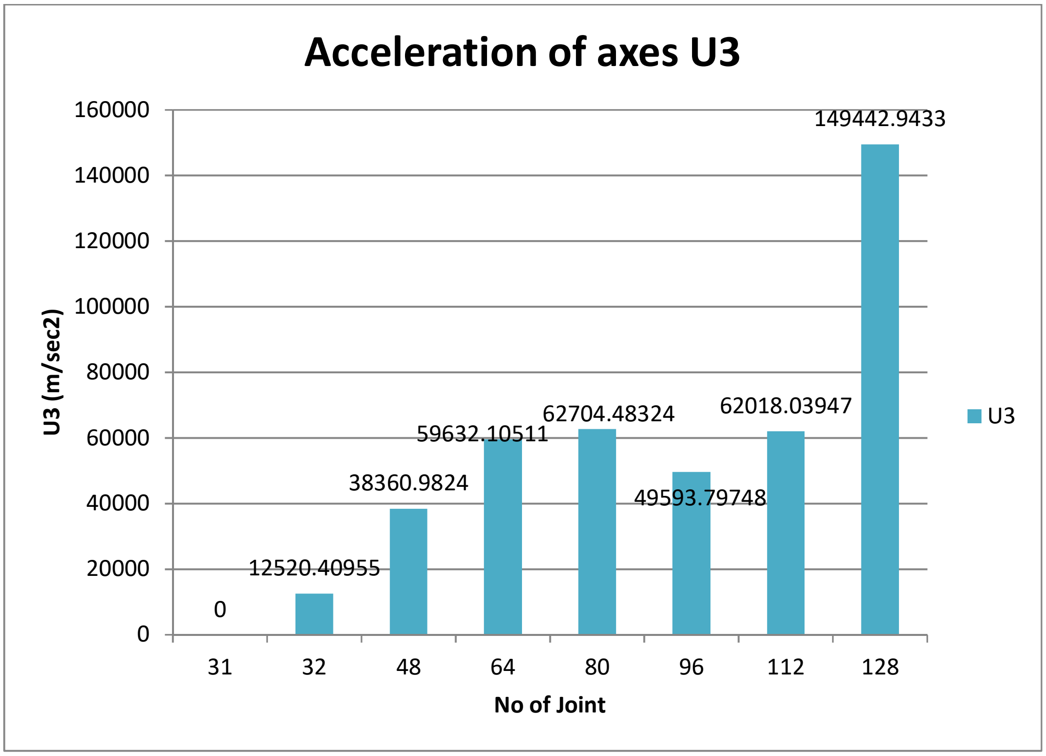


Figure 4.25: Chart no of joint against acceleration of axis U2**.**

Figure 4.25 shows the acceleration of joint at axis U which is U is indicate axis Y . From the bar chart , the highest acceleration occur at joint 128 which is 149442.9433 m/sec2 and acceleration at joint 80 is 62704.48324 m/sec2 where is the second highest among the joint. Joint 112 the third highest with 62018.03947 m/sec2 the value of acceleration and joint 31 are 0 m. The acceleration are occur when the time history are added into simulation.

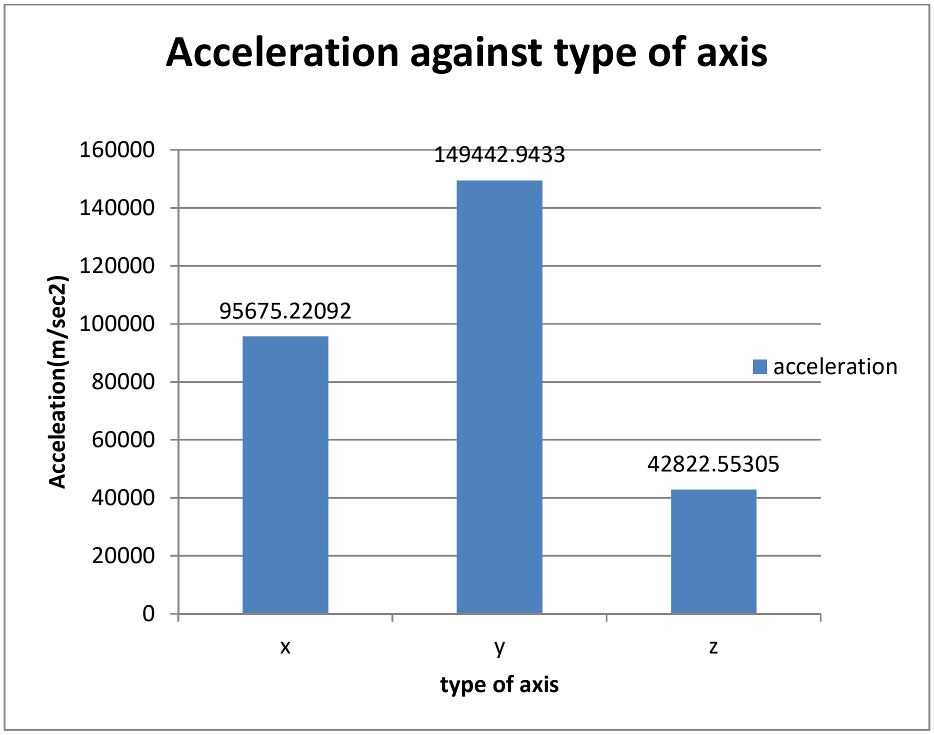


Figure 4.26: show bar chart maximum of acceleration and type of axis

Figure 4.26 show the acceleration at each axis X,Y and Z . The highest average acceleration occur at axes U3 which is indicated axis Y with 149442.9433 m/sec2 . Second highest of acceleration is x axis with value of acceleration is 95675.22092 m/sec2 and followed by axis z with the value of average acceleration is 42822.55305 . From the result we can conclude that , the highest acceleration are occur at joint 128 .

4.5 RESPONSE SPECTRUM

Response Spectrum is simply a plot of the peak or steady state response such as displacement , velocity and acceleration with series of oscillators of varying natural frequency . Response spectra can also be used in assessing the response of linear systems with multiple modes of oscillation (multi-degree of freedom systems), although they are only accurate for low levels of damping. Modal analysis is performed to identify the modes, and the response in that mode can be picked from the response spectrum. To perform seismic analysis or design of a structure , time history are required . Earthquake response spectrum is the most popular tool in the seismic analysis of structure . By using the response spectrum method of seismic analysis for prediction of displacements and member force in structural system .

4.5.1 The response spectrum of displacement of the joint

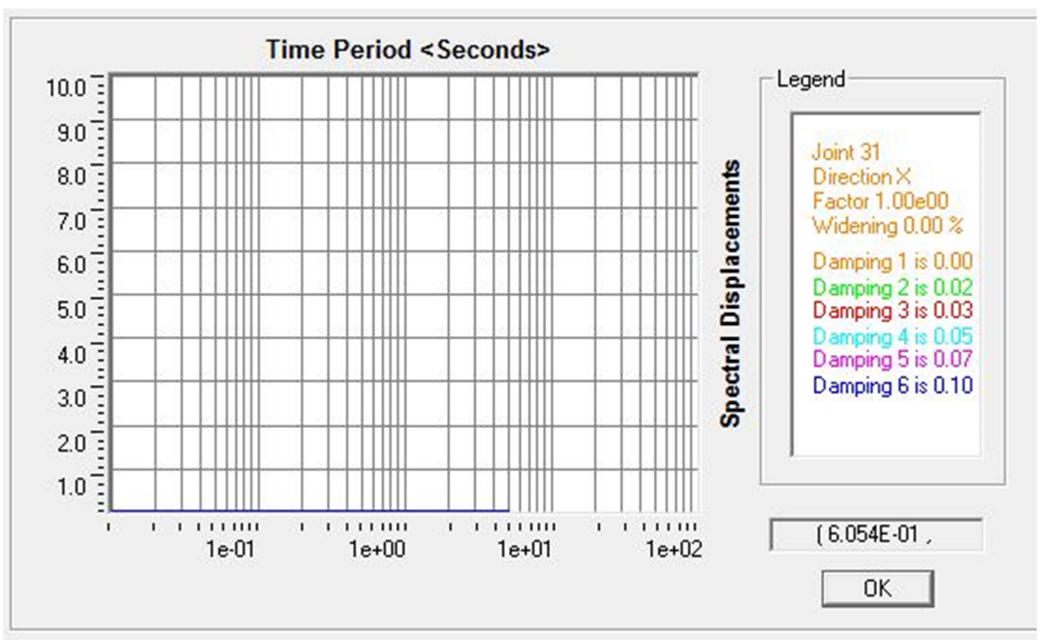


Figure 4.27: graph show the spectral displacement against time period for joint 31

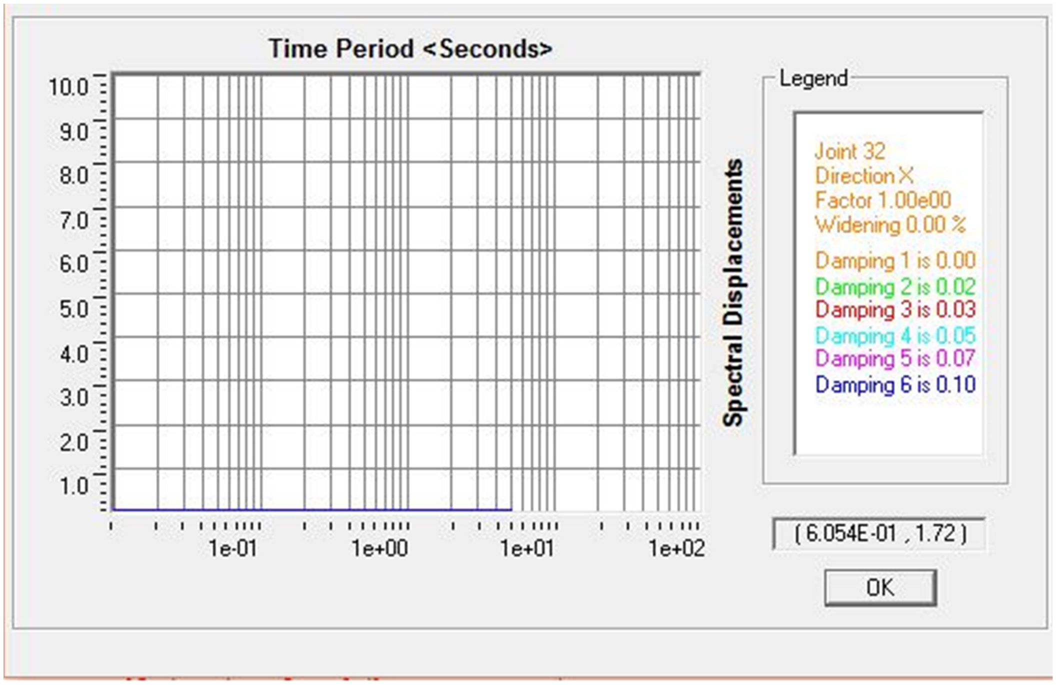


Figure 4.28: graph show the spectral displacement against time period for joint 32

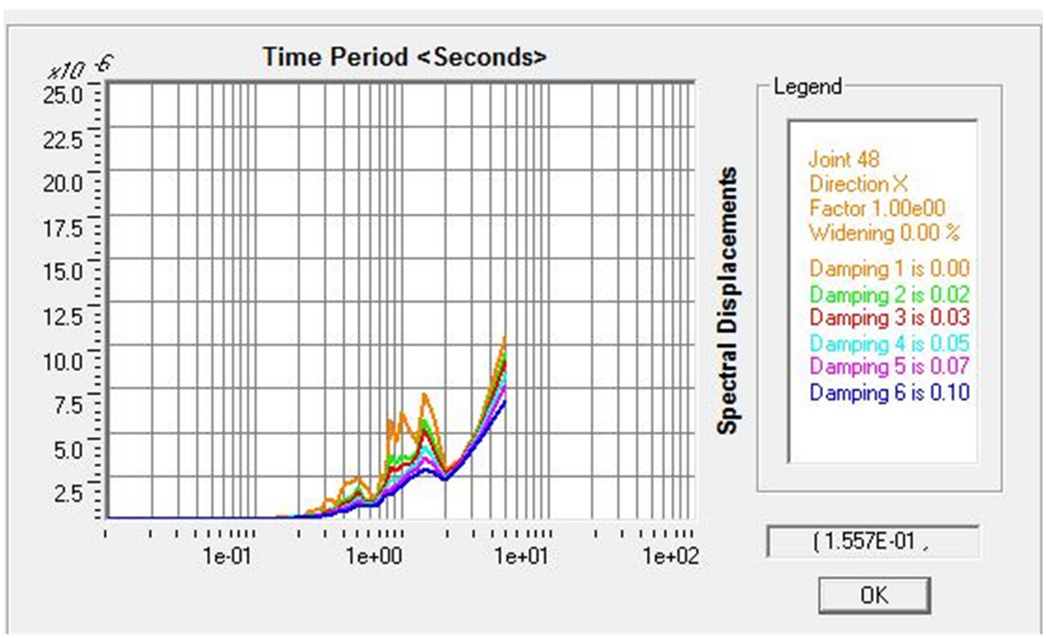


Figure 4.29: graph show the spectral displacement against time period for joint 48

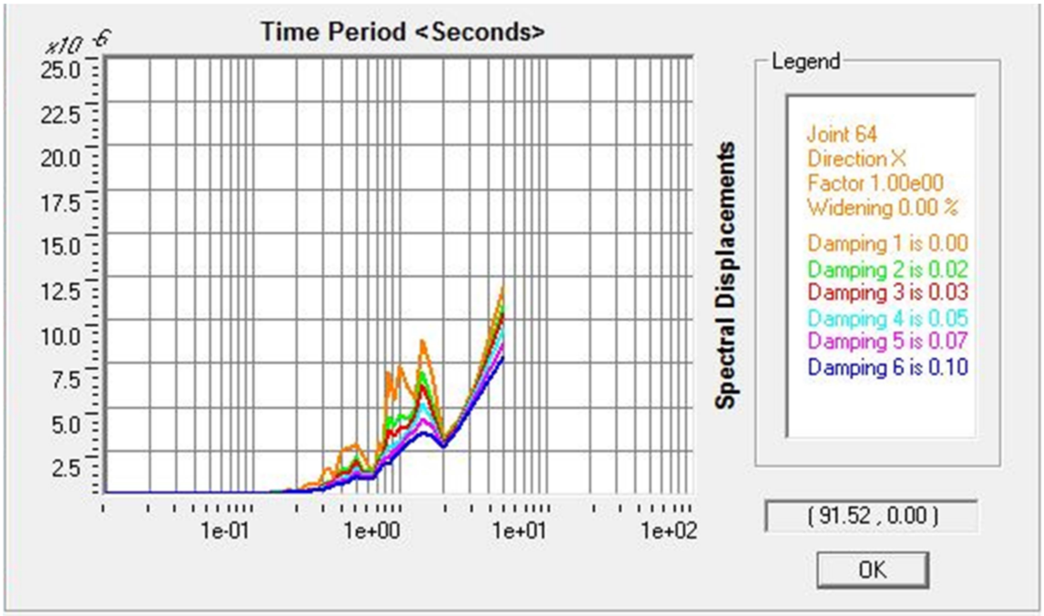


Figure 4.30: graph show the spectral displacement against time period for joint 64

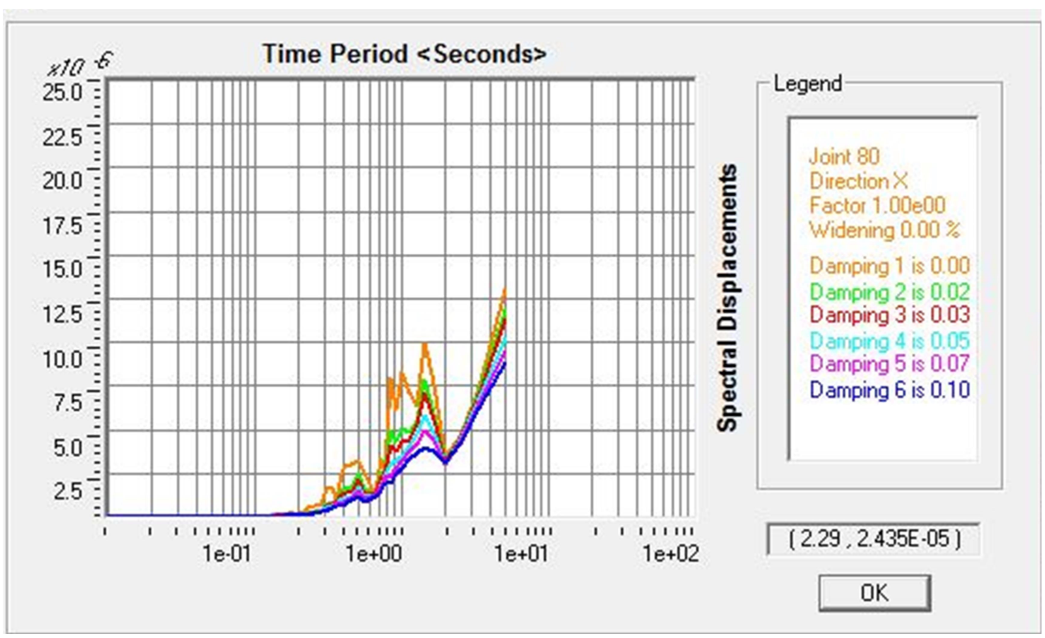


Figure 4.31: graph show the spectral displacement against time period for joint 80

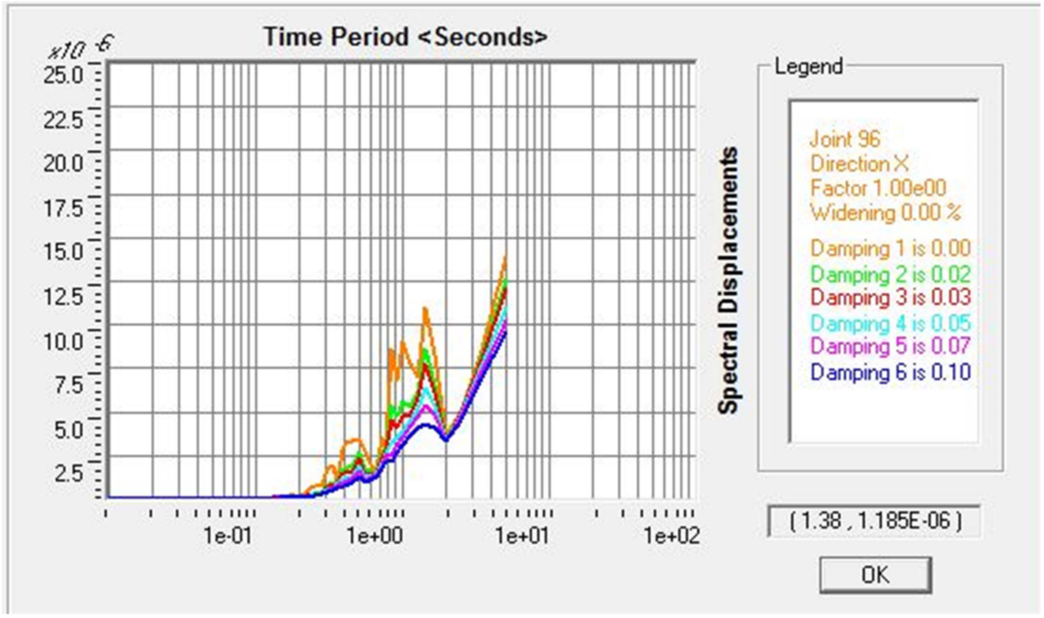


Figure 4.32: graph show the spectral displacement against time period for joint 96

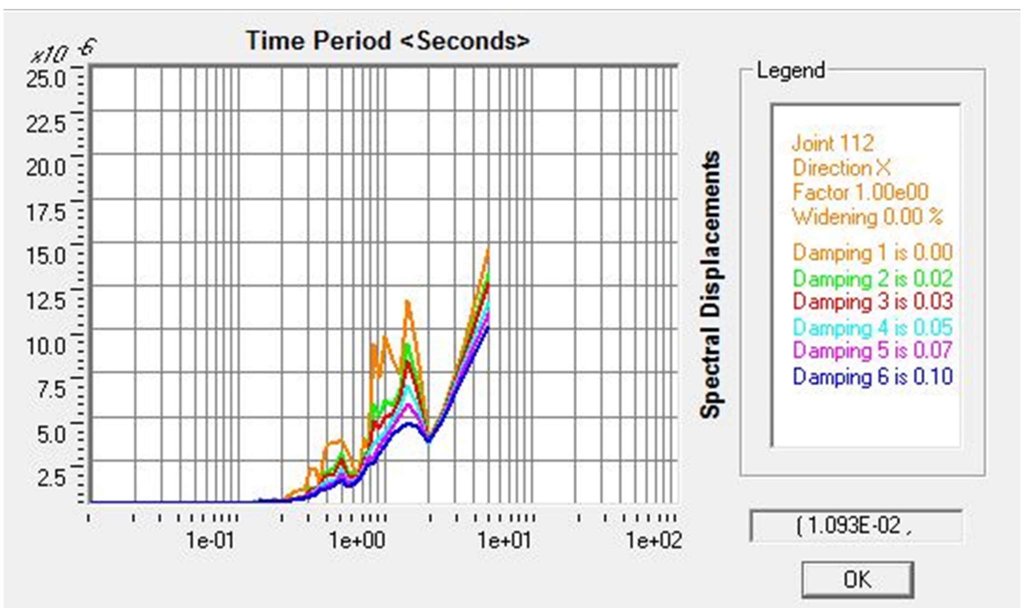


Figure 4.33: graph show the spectral displacement against time period for joint 112

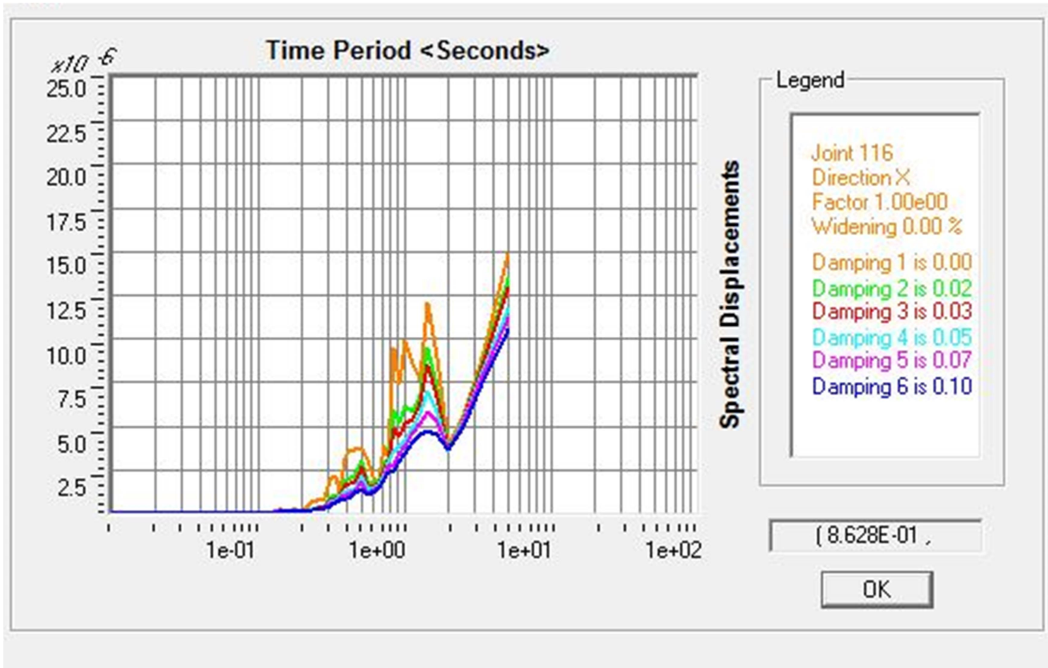


Figure 4.34: graph show the spectral displacement against time period for joint 116

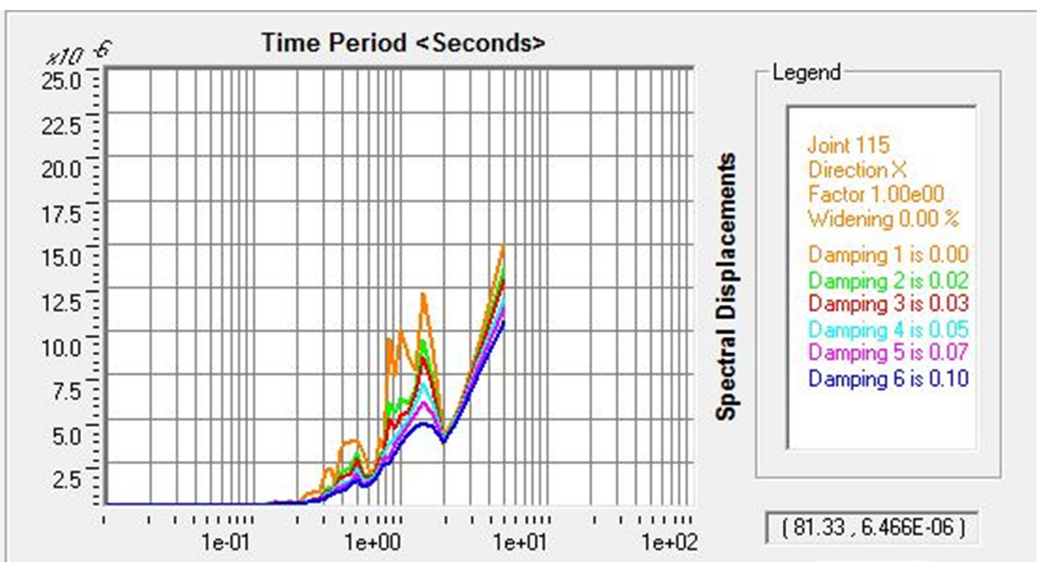


Figure 4.35: graph show the spectral displacement against time period for joint 115

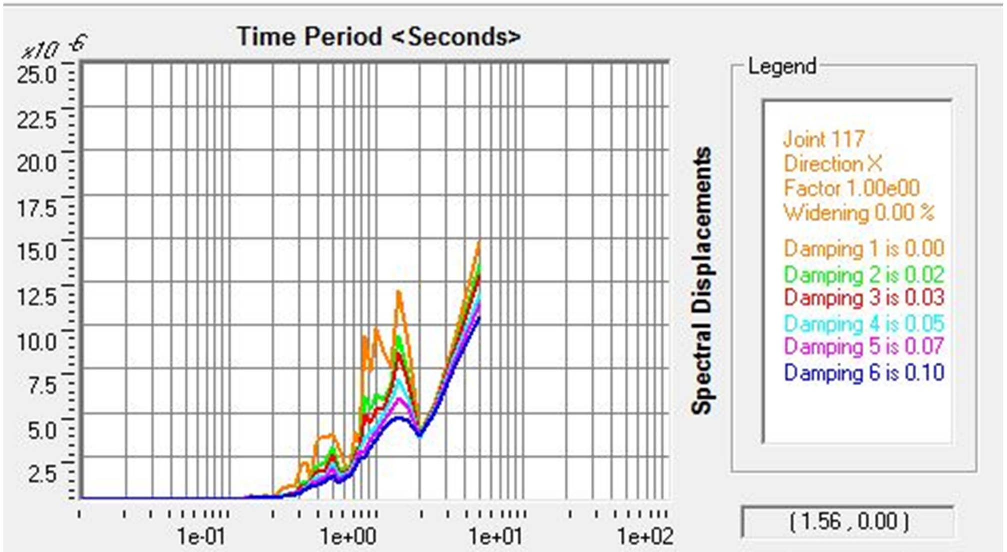


Figure 4.36: graph show the spectral displacement against time period for joint 128

Table 4.2 show the result of displacement at several joint at 5 % of damping

No of joint	Max Displacement at 5% of Damping
31	6.99E-06
32	6.62E-06
48	8.34E-06
64	9.45E-06
80	1.03E-05
96	1.10E-05
112	1.15E-05
128	1.15E-05

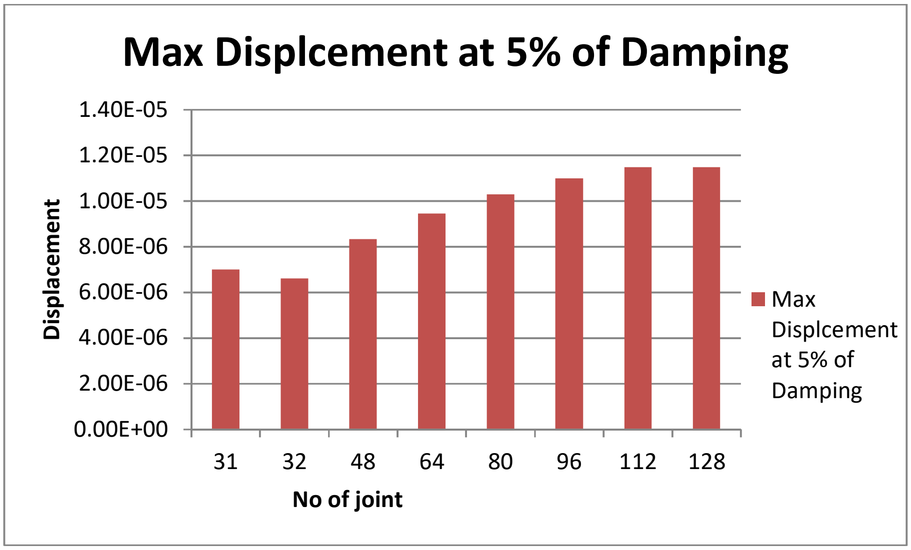


Figure 4.37: show the bar chart the value of displacement against no of joint

The figure 4.37 show the displacement of joint against time period according to the percentage damping of building , from the graph we can conclude that the value of damping are inversely proportional to the value of displacement of joint . When the percentage of damping increase the value displacement the joint are decreased. This is the least amount of damping that will allow the structure to return to its original position without any continued vibration.

To design the building the value of displacement at 5% of damping are used for commercial building and the value of displacement of joint at 0% damping for in the design of an simple vibrator, such as a flag pole or a water tank supported on a single cantilever column.

The biggest displacement are occur at joint 128 and 112 with value 1.15E-05 m and followed by displacement at joint 96 with value of displacement is 1.10E-05 m . The designer can take the value of joint 128 as the maximum value displacement.

4.5.2 The response spectrum of acceleration of the joint

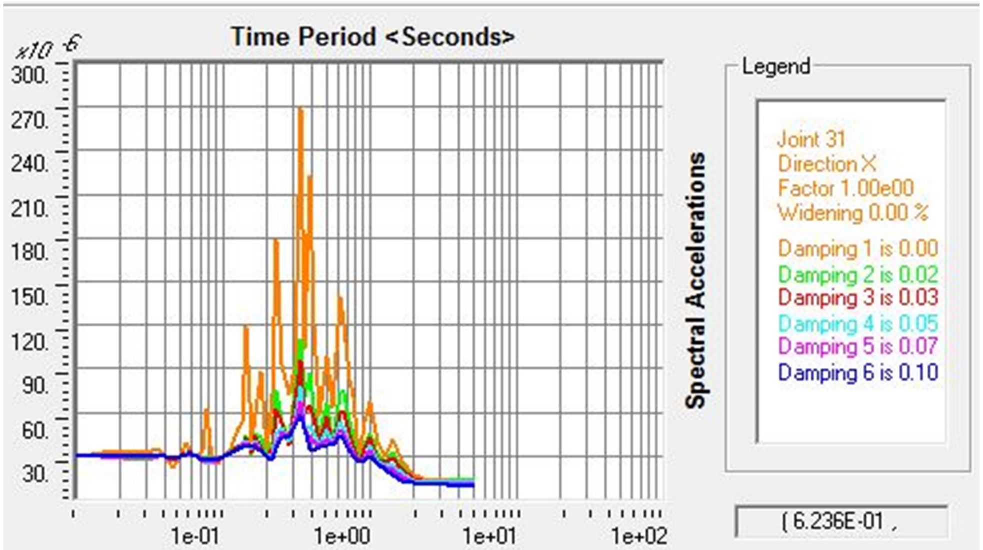


Figure 4.38: graph show the spectral against time period for joint 31

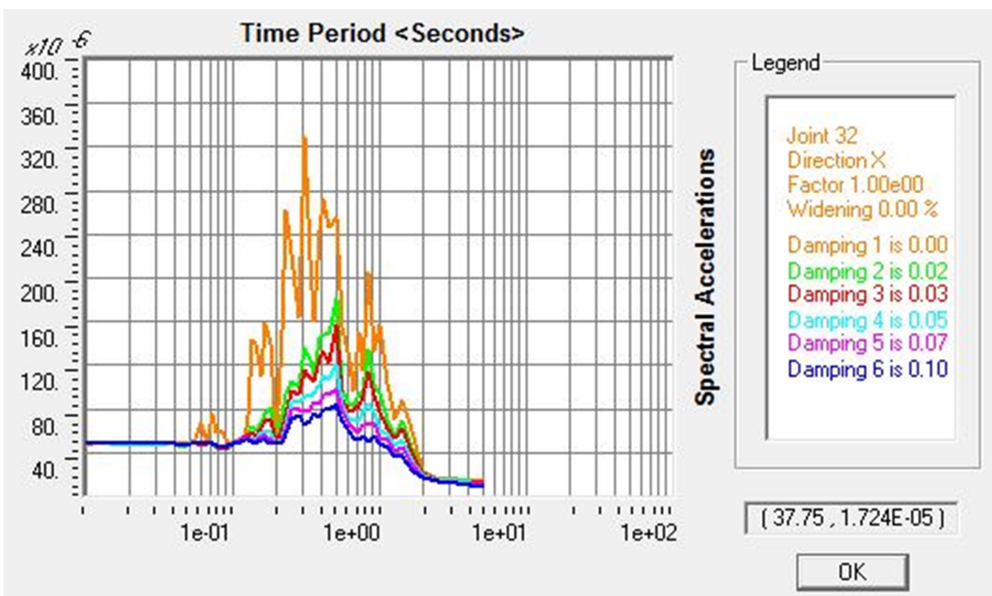


Figure 4.40: graph show the spectral against time period for joint 32

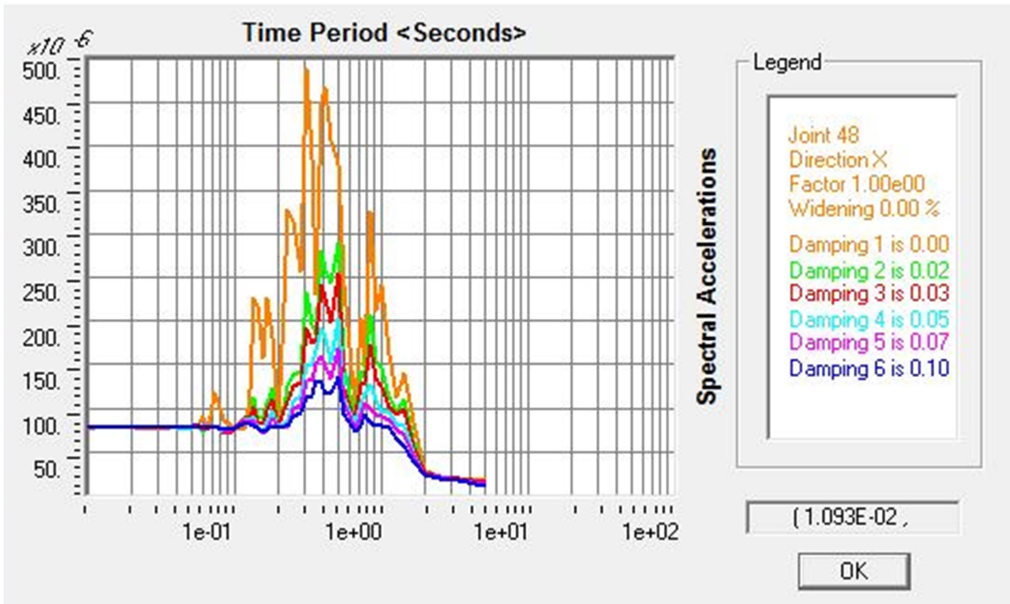


Figure 4.41: graph show the spectral against time period for joint 48

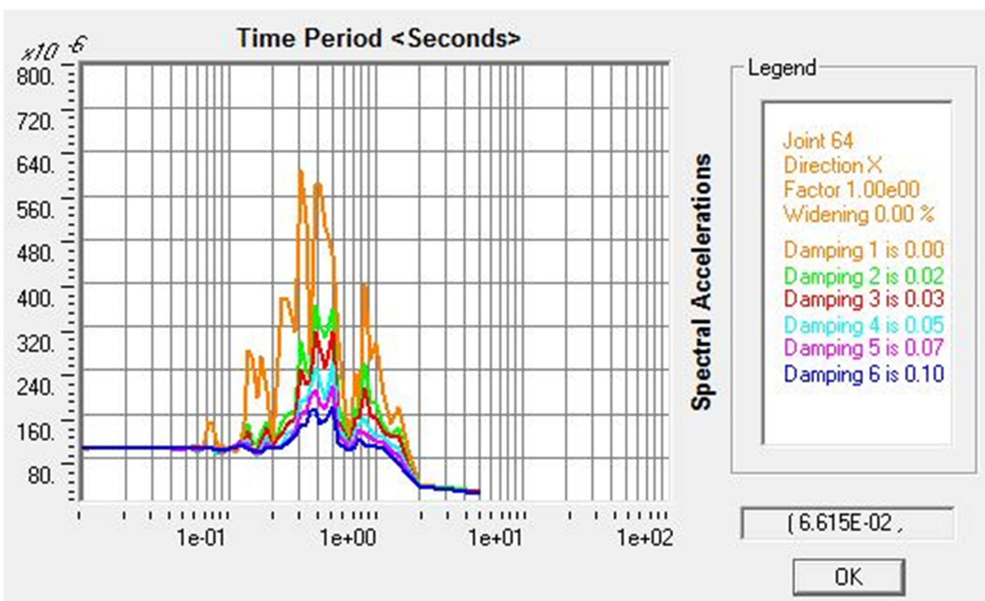


Figure 4.42: graph show the spectral against time period for joint 64

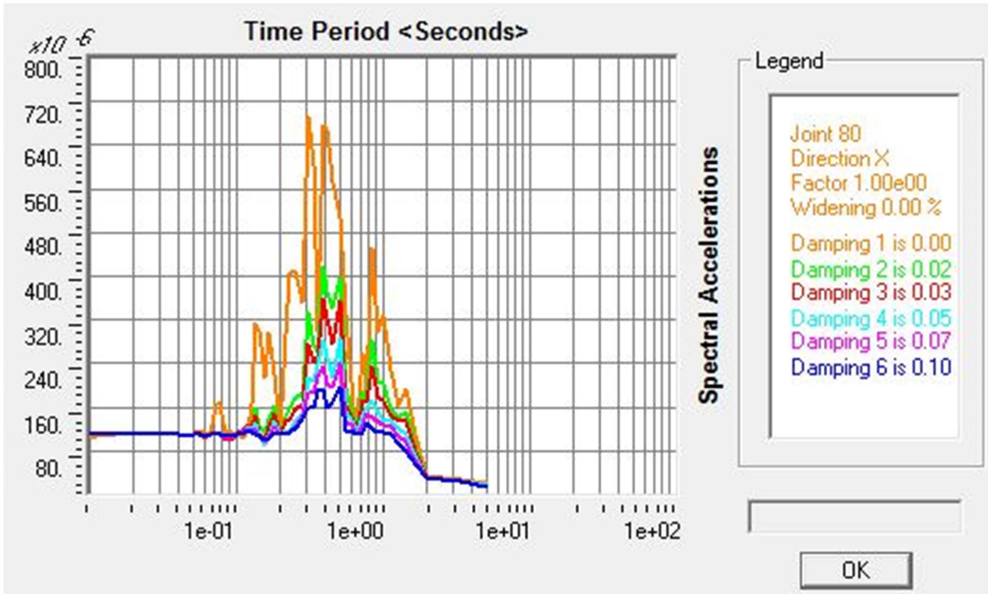


Figure 4.43: graph show the spectral against time period for joint 80

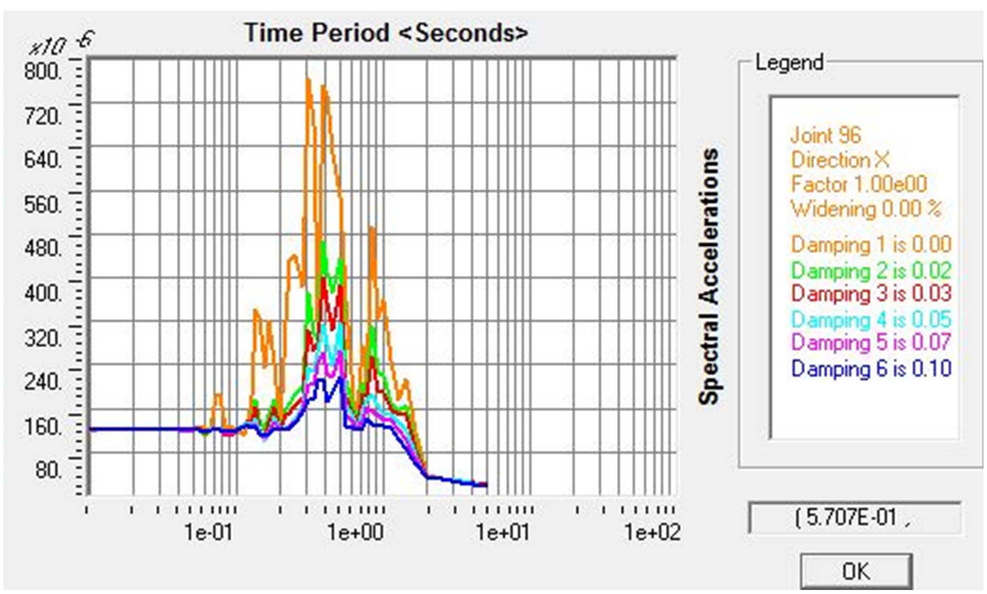


Figure 4.44: graph show the spectral against time period for joint 96

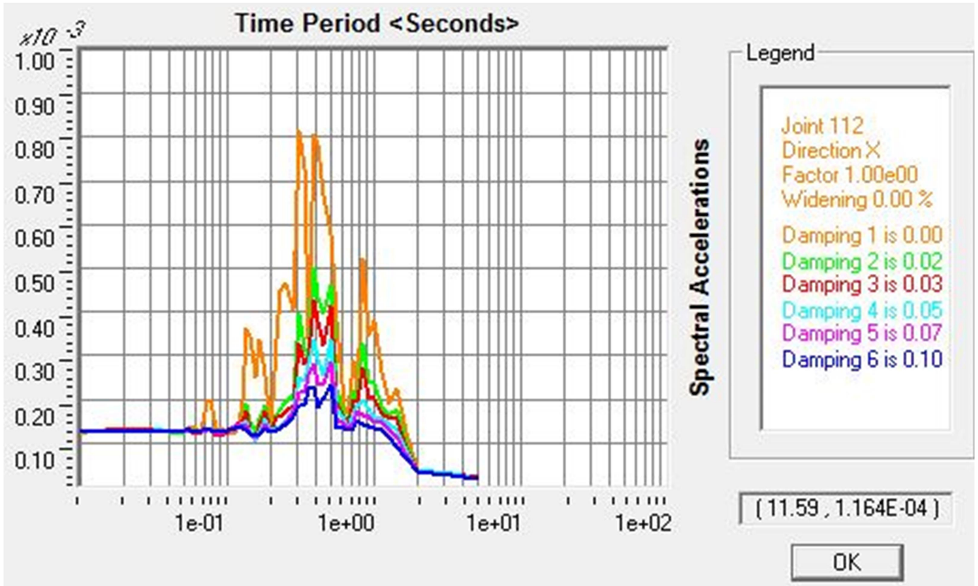


Figure 4.45: graph show the spectral against time period for joint 112

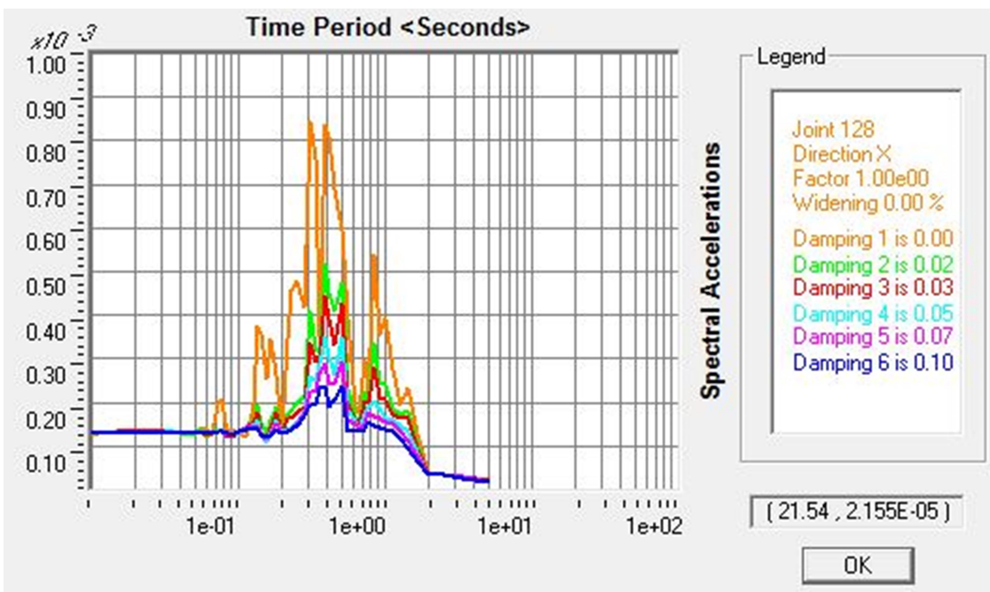


Figure 4.46: graph show the spectral against time period for joint 128

Table 4.3 show the acceleration of joint at 5% damping

No of joint	Max acceleration at 5% of Damping
31	7.81E-05
32	1.21E-04
48	2.03E-04
64	2.06E-04
80	2.84E-04
96	3.16E-04
112	3.37E-04
128	3.50E-04

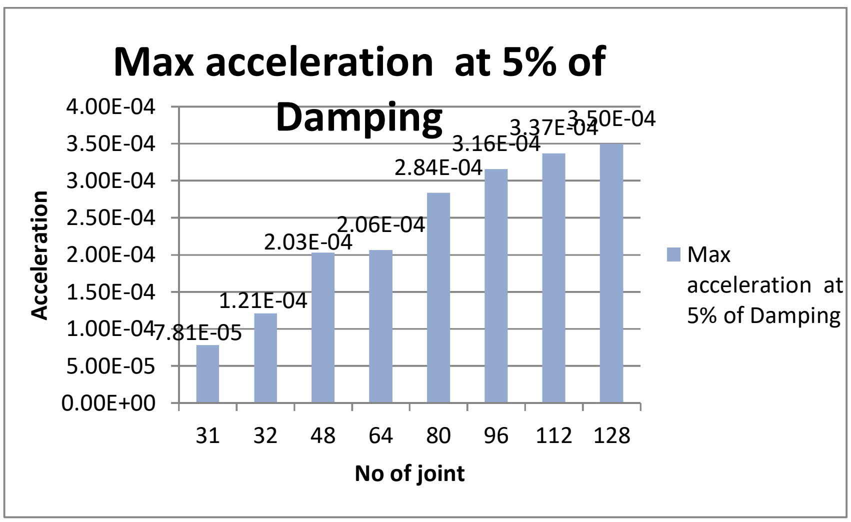


Figure 4.47: Show the bar chart acceleration against no of joint

The table 4.3 shows, the highest acceleration are joint 128 with the value 3.50E-04 m /sec2 and second highest is joint 112 3.37E-04 m/sec2, then, followed by joint 96 . During designing the structure, value of acceleration at joint 128 can be used as the guideline.

CHAPTER 5

CONCLUSSION AND RECOMMENDATION

5.1 CONCLUSSION

Based on the finding of the research, the conclusion that can be made consists of:

i. From the modal analysis , the higher of natural period is 0.014701sec which is from mode shape 1.
ii. The maximum displacement is different according to axis and the joint. The highest displacement occur at joint 128 with the value 0.299743 m
iii. The acceleration is different at each joint and the highest acceleration are at joint 128 with the value 149442.94 m/sec^2
iv. Spectral analysis will show the maximum acceleration and displacement at 5% of damping.

5.2 RECOMMENDATIONS

For the future study , engineer need to design dome structure in Malaysia considering the earthquake load . The tendency of earthquake to happened in Malaysia are lower but the precaution should be taken earlier. Tragedy in Sabah show us that , all future structure should be considered earthquake loading since too many buildings collapse during that day .

REFERENCES

Charleson, A. (2008). Seismic design for architects: outwitting the quake. Amsterdam: Elsevier/Architectural Press.

Victor Gioncu and Federico M . Mazzolani (2011) .Earthquake Engineering for structural design .Preface , first published by Spon Press.

Devastating long-distance impact of earthquakes. (2013, July 23). Retrieved November 25, 2016, from https://www.sciencedaily.com/releases/ 2013/07/ 1307230 73957.htm

Nanette South Clark•PublishedOctober 9, 2014 3:55pm•Monolithic Dome Benefits: Survivability. (2014, October 09). Shake Table Test Shows the Dome Shape is Virtually Earthquake-Proof. Retrieved November 09, 2016, from http://www.monolithic.org/benefits/benefits-survivability/shake-table-test-shows-the-dome-shape-is-virtually-earthquake-proof

Fahjan, Y. M. (n.d.). Effects of dome system on the seismic behaviour of Ottomans historical structures. Retrieved November 09, 2016, from https://www.academia.edu/2452286/Effects_of_dome_system_on_the_seismic_behaviour_of_Ottomans_historical_structures?auto=download.

O.humburger , R. (n.d.). How Earthquakes Affect Buildings. Retrieved November 09, 2017,from http://www.interiorsandsources.com/article-details/articleid /9383/title/how- earthquakes -affect-buildings.aspx

Building Earthquake Resistant Buildings is Best for the Environment and the People. (2011, February 24). Retrieved September 09, 2016, from http://greenbuildingelements.com/2011/02/24/building-earthquake-resistant-buildings-is-best-for-the-environment-and-the-people/

Kusky, T. (2008). *Earthquake: late tectonics and earthquake hazards*. Facts on file .

K.Erdey , C. (2001). Earthquake engineering . US: Hoboken .